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Lackey

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[54] **ROW CARRIER FOR PRECISION LAPPING OF DISK DRIVE HEADS AND FOR HANDLING OF HEADS DURING THE SLIDER FAB OPERATION**

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[51] **Int. Cl.**^{7} **B24B 1/00**

[52] **U.S. Cl.** **451/28**; 451/11; 29/603.16

[58] **Field of Search** 29/603.07, 603.12, 29/603.16, 603.17; 451/28, 41, 11

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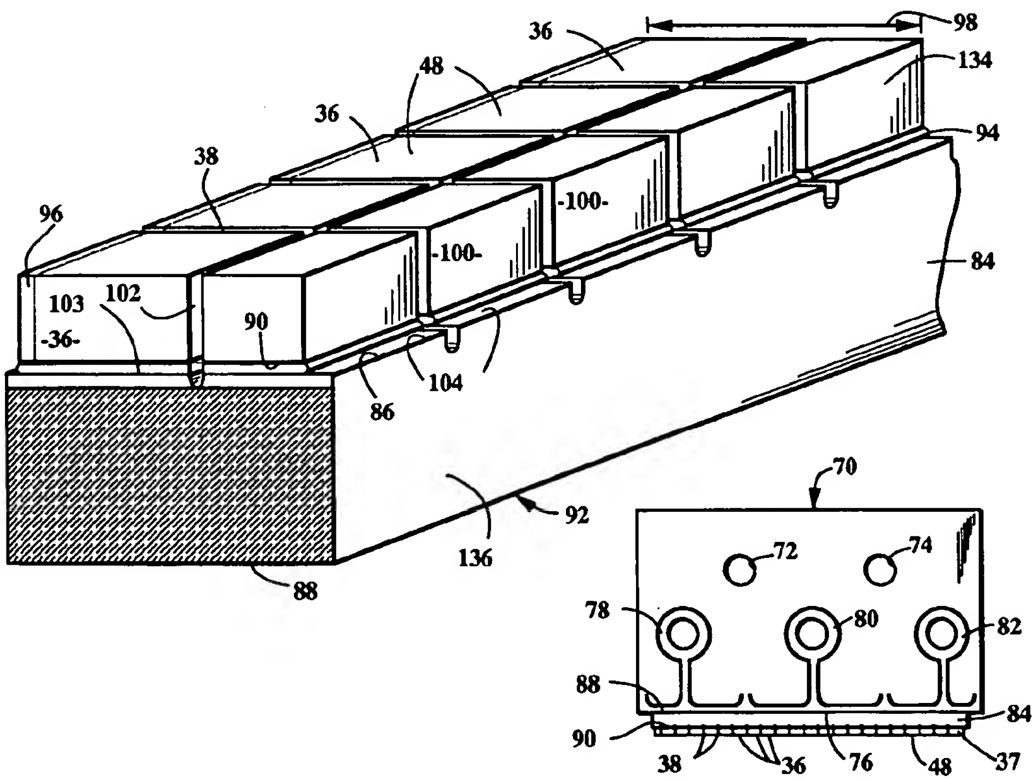
[57] **ABSTRACT**

A row of disk drive slider blanks with magneto-resistive read sensors are lapped after being mounted on the flat surface of a row carrier used to mount the row assembly on a row bending tool. Residual stresses present in the row due to wafer processing are relieved by removing the kerf areas between the slider blanks prior to lapping to prevent the stresses from causing inaccuracies in the lapping process. The stability of sliders below 30% can be enhanced by using wafers thicker than is required and then slicing the extra material from the row of slider blanks after it has been bonded to the row carrier either before or after the lapping process.

18 Claims, 5 Drawing Sheets



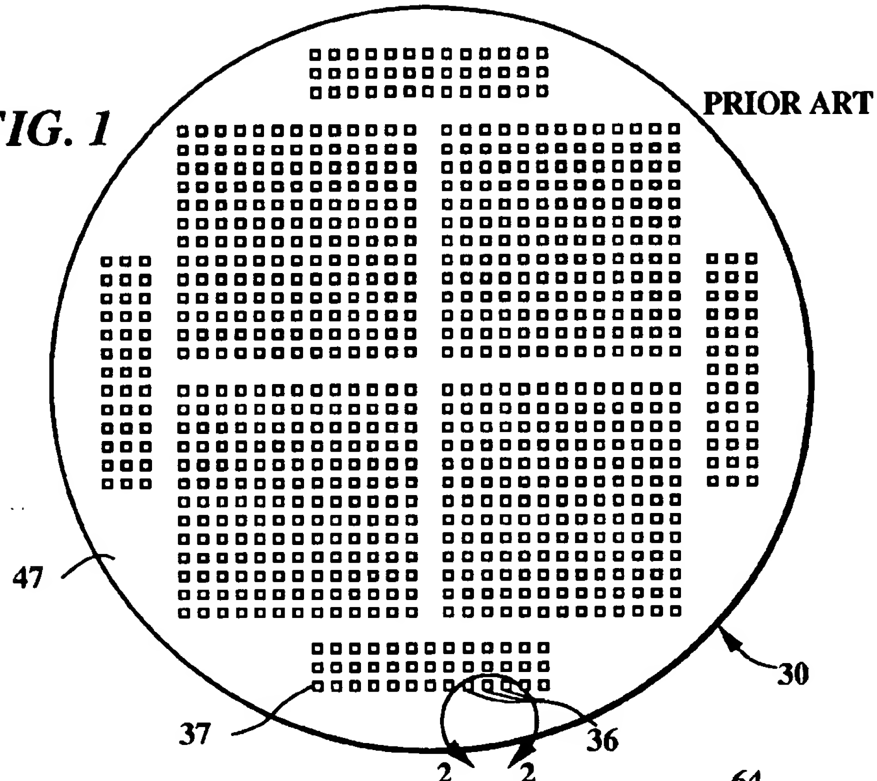
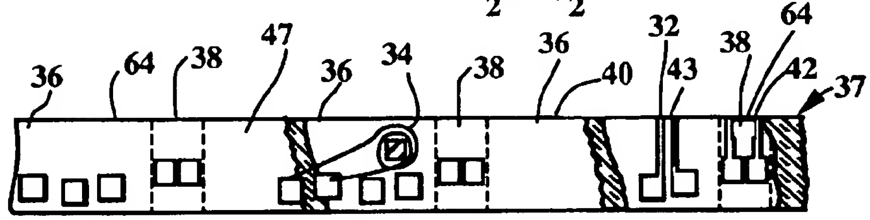


FIG. 1



PRIOR ART

FIG. 2

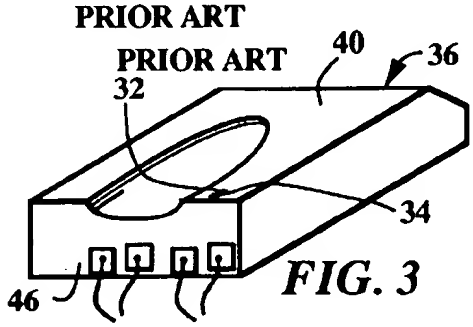


FIG. 3

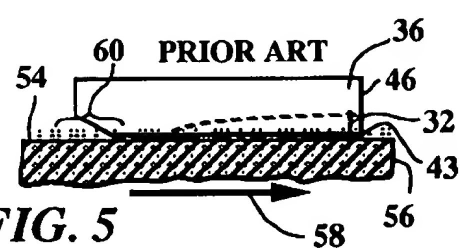
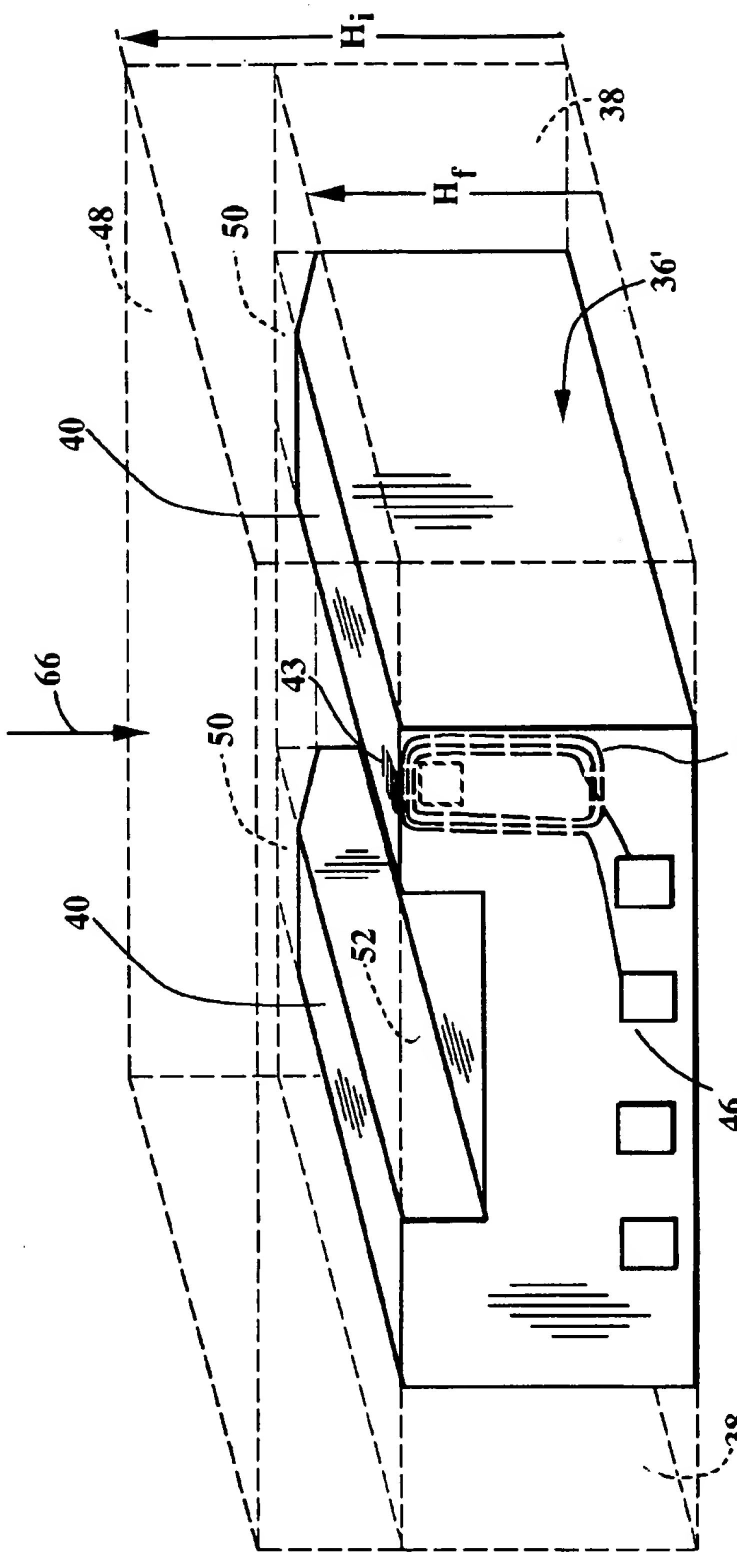


FIG. 5



PRIOR ART

FIG. 4

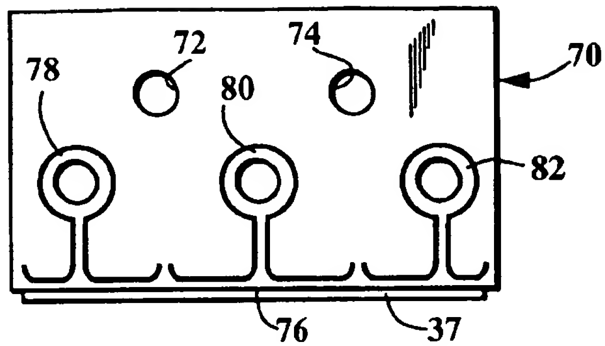
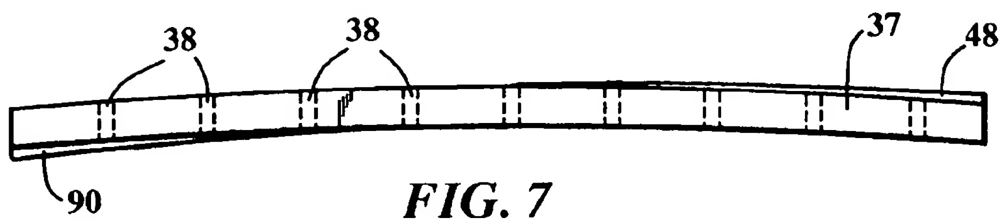


FIG. 6

PRIOR ART



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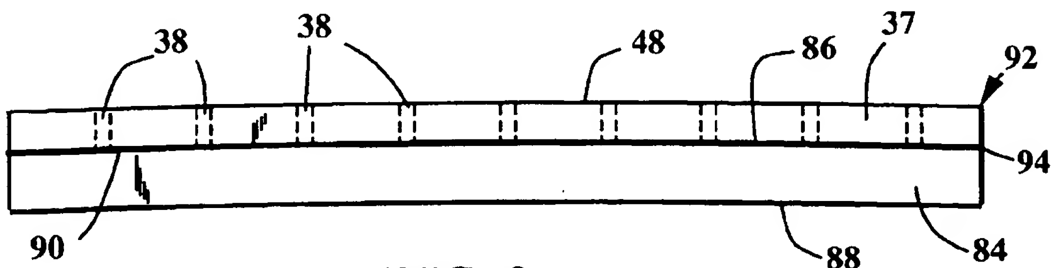

FIG. 8

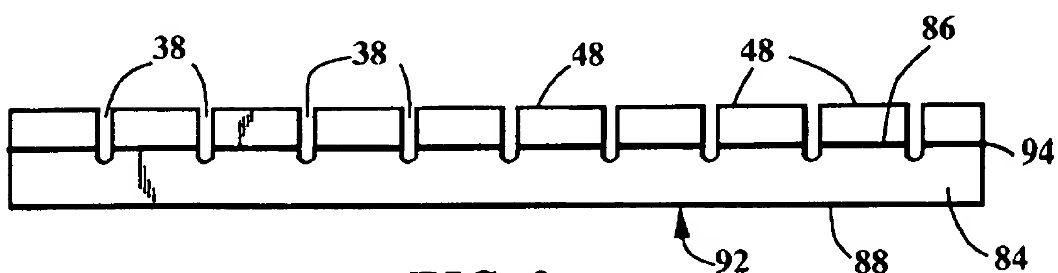

FIG. 9

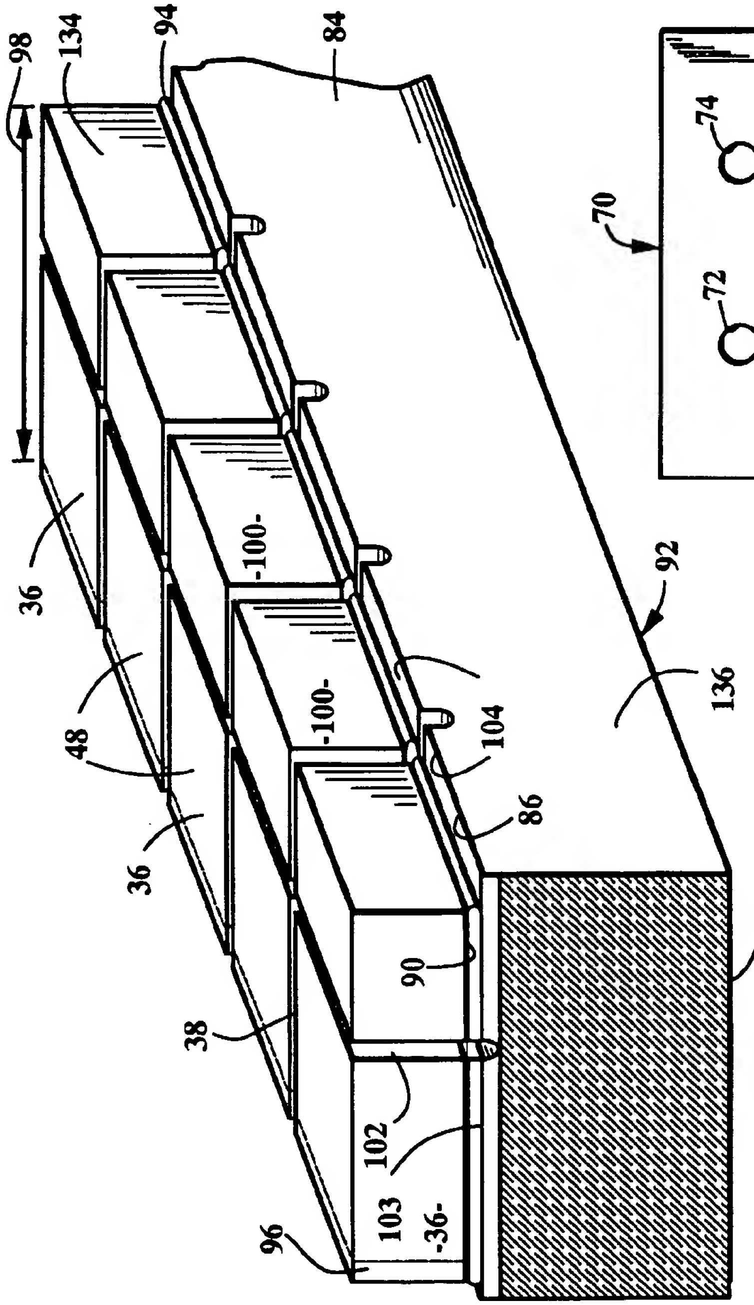
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FIG. 10

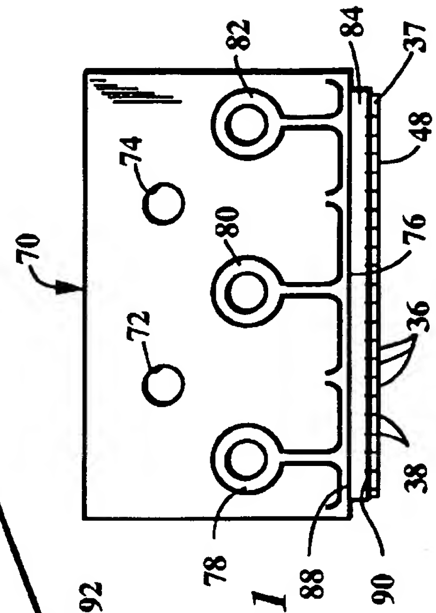
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FIG. 11

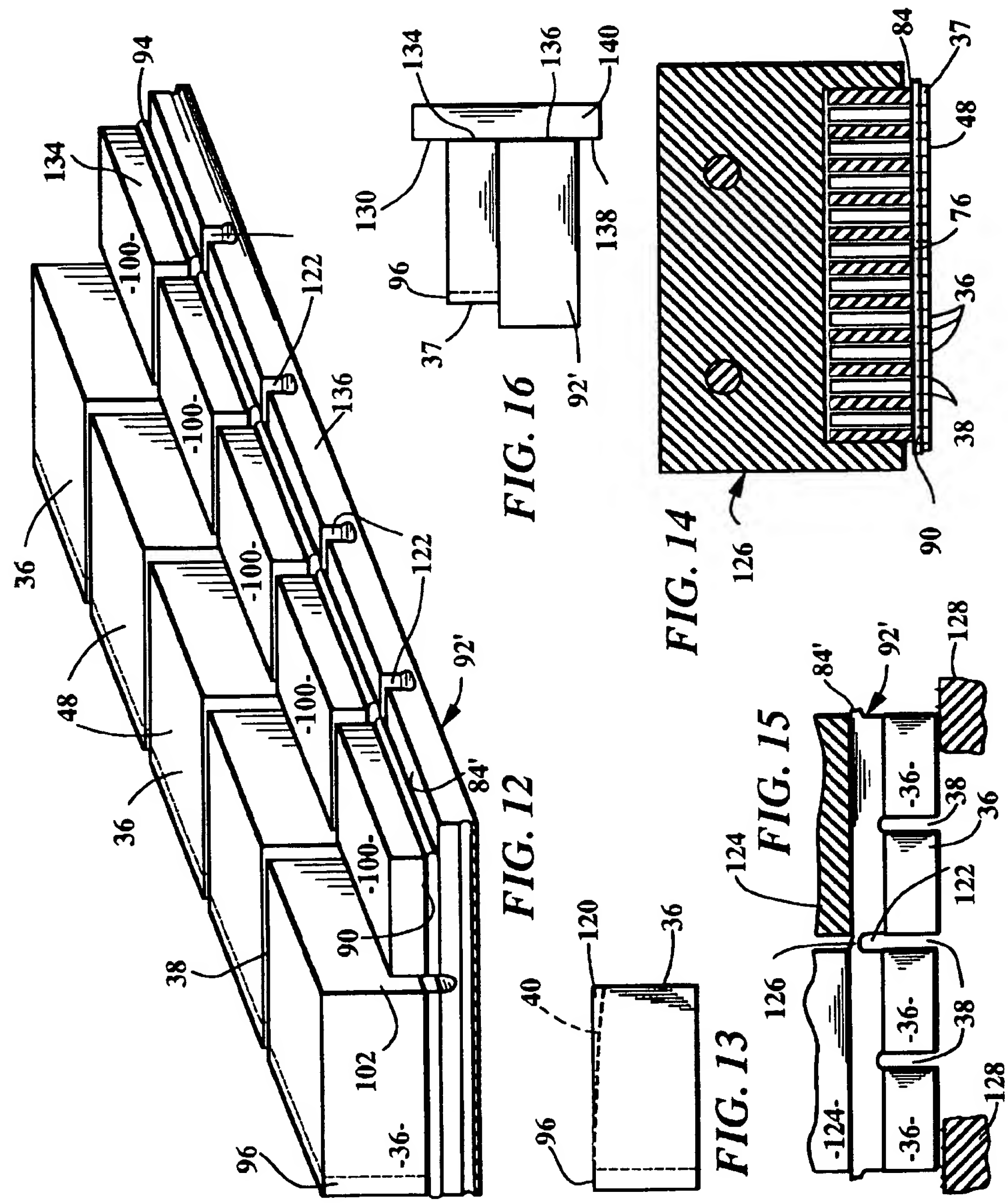

FIG. 12

FIG. 13

FIG. 14

FIG. 15

FIG. 16

ROW CARRIER FOR PRECISION LAPPING OF DISK DRIVE HEADS AND FOR HANDLING OF HEADS DURING THE SLIDER FAB OPERATION

FIELD OF THE INVENTION

The present invention relates to a row carrier that is used for handling the heads during lapping of disk drive heads and is also used for handling the heads throughout the slider fabrication operation. A row of heads is bonded to the row carrier, which is, in turn, bonded to a row tool used on lapping machines. Due to the decrease in the overall dimensions of the advanced technology hard disk heads, there has be a long-standing need for better handing of the heads during the slider fabrication operation since direct handling of the heads can lead to significant yield losses. Heretofore, automated handling has not provided the improvement required for the slider fabrication operation. The row carrier has special importance during the lapping operation since it provides the opportunity to "dice" the heads prior to stripe height lapping. As the requirements for stripe height, crown, twist, PTR (pole tip recession), surface roughness, and cavity depth increase, there has been a long-standing need for improved lapping equipment and processes. The present row carrier permits "single-slider" lapping at the row level by dicing the rows prior to lapping. Lapping at the row level can increase the stresses in the row so that when the row is diced into individual heads, the head twist and the crown of the head change. This slight amount of twist and crown change is unacceptable after dicing for the emerging advanced heads being used in the hard disk drives. These emerging advanced heads will be in full production by 1999.

BACKGROUND OF THE INVENTION

The magnetic devices used to read and write data from the media on a hard disk are called sliders or heads. The previous generation of heads used a single inductive head for both the reading and writing, but such technology could not provide the necessary performance improvements for higher capacity hard disks in high volume production.

Winchester style sliders having thin film, magneto-resistive (MR), giant magneto-resistive (GMR), spin valve, or other types are now being used in magnetic hard disk storage systems to read information magnetically encoded in the magnetic media of the hard disk, with MR elements being the most popular. GMR heads are emerging quickly. A magnetic field extending from magnetic media caused by the spinning of the disk directly modulates the resistivity of the MR element. The change in resistance of the MR element normally is detected by passing a sense current through the MR element and then measuring the changes in voltage across the MR element. The resulting signal is used to recover the digital magnetically encoded information.

Read/write heads are produced by forming the separate read and write elements on a ceramic wafer in a deposition process somewhat similar to that used in the semiconductor industry. The wafer is cut into rows and the slider surfaces are then machined and lapped for proper magnetic and flying height characteristics as described in U.S. Pat. Nos. 5,607,340 and 5,620,356 both by Lackey et al. Tolerances are in the millionths of an inch and are getting tighter as areal densities (the storage bits per unit area) increase. The top surface of the wafer eventually becomes the back surface (trailing end) of the slider, perpendicular to the slider surface (air bearing surface) of the head that forms an air bearing with the media. The electrical resistance of the magneto-resistive material changes when a magnetic field sweeps there through. Normally, a MR head includes a MR stripe having upper and lower sides parallel to the spinning disk media, and conductors that overlay the ends of the stripe at right angles thereto. The conductors define the ends of the stripe and provide the electrical path for the sense current that is used to read the bits of magnetically information. The bits are recorded on the magnetic media by a separate inductive element. The inductive element is formed on the back surface of the head during the wafer process spaced from the MR element.

The change in resistance in a MR element occurs because the magnetic field causes the impedance vector of the material to rotate from a pure resistance, which has the effect of changing the resistance portion of the impedance vector. The effect in the present generation MR elements results in a maximum change in resistance, from 2 to 10%. In the next generations of multi-layer elements, each provide significant improvement, that is the newly available giant MR elements produce a ΔR of about 10 to 30% and the planned colossus MR elements are expected to produce a ΔR of over 30%. The more an MR element changes its resistance when exposed to a magnetic field, the smaller the MR sensor element can be, allowing narrower tracks and smaller magnetized areas, so that more data can be stored per unit area of magnetic media.

The signal to noise ratio of a MR element varies with ratio between the resistance, R of the stripe and the change in resistance, ΔR, of the element when subjected to the sweeping magnetic field. The thickness and to a lesser extent, the composition of a stripe are difficult to precisely control during the wafer fabrication process and therefore a precision lapping process that removes material from the flying surface of the slider is used to trim the height of the stripe to obtain maximum signal to noise ratio. If the stripe is too tall, the resistance is to low with respect to ΔR and the voltage variations due to passing magnetic fields are too low, while if the stripe is too short, the resistance is too high, and the voltage variations due to passing magnetic fields again are too low. In the next generation of heads for drives with even higher areal densities (number of bits per square inch) requiring smaller MR elements, stripe height control to maximize signal output will become ever more critical, requiring lapping to magnetic performance and control on the order of a millionth of an inch. In addition, the stripe height lap and a final crown lap need to be combined since stripe height is reduced by the final crown lap.

MR elements are constructed by laying down thin stripes of MR material using wafer fabrication techniques similar to those developed in the semiconductor industry. The wafer is then sliced so that the MR stripes are positioned adjacent what will become the slider air bearing surface along what will become the trailing or back edge of the slider. Two conductors are formed over each end of the stripes so that the changing resistances due to magnetic fields impinging therein can be measured by a sensing current fed there across.

The most common control approach for lapping uses magneto-resistive electrical lapping guides (MR ELGs) that are formed at intervals along each row of MR elements. Generally MR ELGs are long MR elements with separate connections to the control systems for the lapping machines. In order to find the proper relationship between the stripe height and the measured resistance, it is necessary to calculate the "sheet resistance" of the MR element by finding the sheet resistance of the surrounding MR ELGs. There are many circuit designs for performing this type of calibration of the sheet resistance.

Unfortunately, the resistivity of the MR film varies over each wafer and more particularly over the length of a row of elements on the wafer. Therefore, the resistivity of MR elements distant from a MR ELG and the MR ELG may be different, creating an electrical offset error from head to head and from MR element and the MR ERG. Also, feedback from a MR ELG, which is physically offset from the MR element whose height it is trying to control, creates a physical offset error. This may seem minor, but if the distance between a MR ELG and the MR element whose height its is controlling is 0.008 inches and the desired control is 1 microinch, this is a ratio of 1 to 8,000. Some data scatter is also attributable to imprecise formation of the MR stripes.

One solution for variations in sheet resistivity and stripe variations suggested in the past was to measure the resistance of an MR element as its height is being trimmed during the lapping operation. With prior technology, direct measurement has been only marginally acceptable. Since the MR elements are microscopic, there is often a large error between actual stripe height and measured resistance. There also is a "blurring" of the contact between the ends of the MR element and the conductors. Since the MR element is short, this blurring becomes a significant percentage. Separate MR ELGs are typically 10 to 20 times longer than the MR element, which minimizes this "blurring" error. Also, to sense the resistance of MR elements directly requires electrical connections and disk drive manufacturers typically do not want wire bonding marks that result from the bonded connections nor probe card marks, present on the MR element bond pads, because such can adversely affect the reliability of new wire bonds or pressure connections when pressure contact pads are employed.

Current fabrication techniques cannot maintain the needed control of sheet resistance so the width of the stripe is critical to get the optimal response from the MR element, which is a function of element resistance and ΔR resistance due to the impingement of a magnetic field. Therefore, a lapping operation of the slider air bearing surface has been used to adjust the width of the MR strip to an accuracy of several millionths of an inch with processes, machines, and devices such as shown and described in U.S. Pat. Nos. 5,607,340 and 5,620,356, both by Lackey et al.

During head production, batch fabrication is employed whereby a plurality of transducers are sliced from a ceramic wafer in a row and bonded onto a row bending tool for stripe height lapping. Row bending tools are commonly constructed from ceramic or steel in a configuration of flexures that allow forces applied to a row bending tool to deform the attached row in up to a fourth order curve in a single plane. During the manufacture of the sliders, this allows a plurality of MR transducers to have their stripe height to be precisely lapped to achieve a desired stripe height at which optimum data signal processing can be realized. The stripe height of all the transducers made during a production run for use with a data storage product must be maintained within a defined limited tolerance.

The process steps performed on the wafer generate residual stresses, which can cause the rows to bend when they are sliced away from the rest of the wafer, a condition known as "row bow". Although the level of stress can be reduced through care in the wafer fabrication process, it can not be eliminated. Also some manufacturers have processes where reduction of residual stress is not stressed as much as others. Although a curved row theoretically can be straightened for lapping by bonding it to a row bending tool, the stresses are not always uniform across a row, resulting in kinking of the row during bending in the lapping operation. The result is a wide variation in stripe heights across the row after the lapping operation. This variation in stripe height affects ultimate process yields as MR elements get smaller. As a result, MR sensors can not be properly lapped with high yields at the very close tolerances needed when sliders below 50% (>2.05 mm length×1.6 mm width×0.43 mm thick), that is 50% of an early initial slider standard of 4.02 mm length×3.2 mm width×0.86 mm thick, are constructed. Also, such sliders present such a small surface opposite the surface to be lapped that they are difficult to mount to a row bending tool and lap to the desired slider surface shape.

Prior attempts to correct for ceramic bar or slider bar distortion are disclosed in U.S. Pat. Nos. 5,117,539 and 5,203,119, 5,607,340, and 5,607,340. However, none are totally satisfactory, when extraordinary care is not used in the wafer processing to minimize residual stresses. Therefore, a long standing need has existed to provide an apparatus and method to relieve residual stresses in a row of sliders and to accurately mount it on a row bending apparatus so that MR sensor stripe height on a plurality of sliders in the row can be accurately controlled during lapping by accurately bending the row or varying the lapping pressure of individual heads.

Also, there has been a long-standing need for handling the individual heads during the slider fabrication operation. The bonding on the row during lapping is just one of a plurality of bonding and debonding operations. As the row and the heads become smaller and more fragile, there is a yield loss during each bonding and debonding operation. After the row is bonded to the row carrier after slicing, the row carrier becomes smaller and more fragile, there is a yield loss during each bonding and debonding operation.

BRIEF DESCRIPTION OF THE INVENTION

When rows of sliders are cut from the wafer, some residual stresses from the manufacturing processes are always present causing curvature from bottom to top, but little side to side curvature because the row is wider than tall. In the present invention, the under surface of a row of MR sensor sliders is bonded to a flat surface (preferably optically flat) of a elongate row carrier having an opposite and parallel surface for bonding to a row bending apparatus. The row carriers may be made from ceramic, steel or other physically stable materials that are compatible with other process steps. Ceramic row carriers are relatively easy to manufacture with precisely formed surfaces and are preferred because the thermal expansion coefficient of ceramic can be matched to the thermal expansion coefficient of the wafer material. However, steel is preferred when movement between adjacent sliders is desired and the brittleness of ceramic prevents such movement. The row carrier is chosen to be as stiff or stiffer than the row, usually by having fore to aft and top to bottom thickness so bonding tends to straighten the row of sliders. However, at the extreme accuracy that slider heads now require, the slight bending of the ceramic carrier caused by the initial stresses induced by the row of sliders and changing stresses as the row of sliders is lapped, can introduce error. Therefore, once the row of sliders is bonded to the carrier, the row may be diced (usually by sawing with a fine saw) to separate all of the sliders. If the row is diced, this further reduces stresses that can develop to undesirably deform the carrier to such an extent that down to 5% sliders can be properly lapped using available technology. If row bending apparatus are to be used, the saw cuts only extend into the carrier far enough to assure that all sliders are separated from each other. When apparatus that applies

pressure to individual heads is used, the saw cuts preferably extend almost through the carrier or it is cut almost completely through in advance. By lapping the sliders individually after dicing, the residual stresses are removed much better that if not diced before lapping.

The row carrier becomes a carrier for the row for handling purposes so that individual sliders do not need to be directly handled.

When a row is lapped without dicing, the residual stresses remain in the row. After dicing the sliders can twist, which could cause the slider to be rejected unless another lapping operation is performed. This operation, called a touch or crown lap, while removing the twist and other lapping problems, causes the stripe height (and its magnetic performance) to be degraded to an unacceptable level. Also, when lapping the row (without dicing on the row carrier) the row bending equipment used for dynamic row bending can put stresses into the row during the bending to correct for the row bow.

The fore to aft dimension of a slider row is determined by the thickness of the wafer. Wafers become so thin that stress inducing fabrication steps cause them to bend like a "potato chip" after being debonded from the wafer carriers.

In the present invention, thicker wafers may be used so that the fore to aft dimensions of the sliders are larger than needed. Then, once the row of sliders is bonded to the row carrier, the extra material can be separated from the row of sliders by dicing the row parallel to the surface thereof on which the MR sensors are formed. The extra material remaining on the row carrier can be retained to stabilize the row of sliders during lapping or it can be ground away to allow lapping of just the slider surface. After lapping has established the proper stripe height of the MR sensors in a row, the sliders can be retained on the row carrier for further batch process steps or the sliders can be debonded therefrom for further individual process steps.

Therefore, it is an object of the present invention to reduce the residual stresses in a row of hard disk drive sliders with MR sensors formed thereon, so that accurate lapping of the stripe height of the MR sensors can be accomplished for small sliders, either by row bending or individualized pressure applied to the sliders.

Another object is to allow the batch manufacture of MR sensor containing hard disk drive sliders in sizes less than 30%.

Another object is to provide means for accurately lapping MR sensor sliders and holding the sliders for further process steps.

Another object is to reduce the handling required to fabricate MR sensor sliders, and thereby reduce electrostatic discharge damage thereto.

Another object is to mechanically stabilize MR sensor sliders during lapping operations.

Another object is to provide a convenient handling jig and method for automated inspection and for automated measurement since most of the present automated inspection and automated measurement have complex and expensive handling mechanism for single-slider processing, which is eliminated with the present row carrier.

These and other objects and advantages of the present invention will become apparent to those skilled in the art after considering the following detailed specification, together with the accompanying drawings wherein:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a plan view of a prior art wafer used to construct disk drive sliders;

FIG. 2 is an enlarged detailed view of a portion of a bar of sliders taken generally from the area 2—2 of FIG. 1;

FIG. 3 is an enlarged perspective view of a completed slider;

FIG. 4 is an enlarged perspective view of a slightly different slider showing areas of the wafer bar removed during the fabrication process;

FIG. 5 is an enlarged side elevation view of a slider, aerodynamically flying over the magnetic media of a hard disk also showing the magnetic fields extending from the disk which are read by the slider;

FIG. 6 is a side elevation view of a row of sliders attached to a prior art row bending tool;

FIG. 7 is an enlarged side elevational view of a row of sliders showing a greatly exaggerated possible curvature that can occur after the row has been sliced from the wafer of FIG. 1;

FIG. 8 is an enlarged side elevational view of the row of sliders of FIG. 7 after it has been bonded to a flat surface of a row carrier;

FIG. 9 is an enlarged side elevational view of the row of sliders and row carrier of FIG. 8 after the row of sliders have been diced into individual sliders;

FIG. 10 is a partial cross-sectional of a perspective view of FIG. 9;

FIG. 11 is a side elevation view of the sliders and row carrier attached to a row bending tool;

FIG. 12 is a partial cross-sectional perspective view similar to FIG. 10 of a row carrier and row designed for individualized slider stripe height control;

FIG. 13 is a side elevation view of a slider, showing the curvature that some manufacturers desire;

FIG. 14 is a cross-sectional elevational view through the row carrier of FIG. 12 attached to an apparatus for applying different lapping pressures to each slider;

FIG. 15 is an enlarged cross-sectional elevational view similar to FIG. 14 showing the fingers of the apparatus of FIG. 14 displacing two sliders at a time; and

FIG. 16 is a side elevational view showing one method of aligning a row of sliders with a row carrier.

DETAILED DESCRIPTION OF THE SHOWN EMBODIMENTS

In the Figures that follow, the invention is illustrated, but the scale and form of the components are not always exact. Referring to the drawings more particularly by reference numbers, number 30 in FIG. 1 refers to a ceramic wafer, such as those used in forming magneto-resistive (MR) sensors 32 from MR thin films and electro-magnetic writing heads 34 on disk drive sliders 36, as shown in FIG. 2.

FIG. 2 is a portion of a row 37 of sensors 32 and writing heads 34 as they are formed on the wafer 30 and cut therefrom. The row 37 includes a plurality of what will be disk drive sliders 36, as shown in FIGS. 3 and 4, separated by kerf areas 38, which are removed during sawing or dicing of a finished row 37 to separate the sliders 36. The MR sensors 32 cannot be formed and placed with the exactitude required for high performance disk drives. Therefore the flying or slider surface 40 is lapped until the MR sensors 32 have optimum electrical characteristics. Typically, the progress of the lapping process is monitored with electrical lapping guides (ELGS) 42 positioned at spaced intervals along the row 37 in the kerf areas 38. To obtain high accuracy, ELGs 42 are ten to twenty times wider than the

MR elements 43. Due to the small size of each MR element 43 and the inability of present processes to maintain a constant sheet resistance across a wafer 30, there may be a large error between actual stripe height and measured resistance. There is also a "blurring" of the contact between the ends of the MR elements 43 and their conductors. Since the MR element 43 is short, this blurring can becomes a significant percentage of the total resistance, which is to be measured. By making the MR ELG 42 ten to twenty times longer than the MR element 43, this blurring error is minimized.

As aforesaid, the resistivity of the MR film forming the elements 43 typically changes over the length of a row 37 on a wafer 30 and therefore, the resistivity of an MR element 43 and a MR ELG 42 spaced at a distance therefrom may be different, creating offset errors from slider 36 to slider 36. Offset errors are also created by imperfections in the photolithographic process used to position the MR sensors 32 and ELGs 42 on the wafer 30. Feedback from a MR ELG 42, which is physically offset and out of alignment with the device it is trying to control creates an offset error. This may seem minor, but if the distance between an ELG 42 and the MR sensor 32 is 0.008 inches and the desired control is 1 microinch, this is a ratio of 1 to 8,000.

FIG. 3 shows the slider surface 40 of the slider 36, which is the surface that is lapped to form the MR sensor 32. Normally MR sensors 32 are formed just under the rear surface 46 of the slider 36 by first laying down the MR sensor 32 and then forming the write head 34 on layers there over. The details of the rear surface 46 shown in FIG. 2 are shown with protective layers 47 both on the back surface 46 cut away.

FIG. 4 shows a modified slider 36'. The ceramic material normally removed to form the slider 36' is shown in dotted outline. After a rough lap or grinding operation to remove excess material left at slicing on the row 37, generally the layer 48 is lapped away as the lapping progress is monitored by the ELGs 42 (FIG. 2). Then material at the kerf areas 38, the leading edge wedges 50, and a slot 52 is milled away, such as by ion milling. The slot 52 may be the length of the slider 36' or just a portion thereof as shown in slider 36 of FIG. 3. When properly manufactured, a slider 36 will aerodynamically fly just over the surface 54 of the disk 56 of a disk drive, as shown in FIG. 5. The relative movement of the disk 56 with respect to the head 36 is shown by the arrow 58. The write head 34 magnetizes small areas of the disk 56, which produce a pattern of magnetic fields 60. When the magnetic fields 60 pass through the MR element 43, the electrical resistance thereof is reduced. The reduction in resistance is sensed by passing a sense current through the MR element 43 and monitoring the voltage changes created thereby.

MR elements 43 are thin film devices. Since the manufacturing process for such thin films cannot be precisely controlled, the thickness and the bulk characteristics of the element 43 cannot be precisely controlled at the wafer level. In order to find the proper relationship between the stripe height and the measured resistance, it is necessary to calculate the "sheet resistance" of the MR element 43 by finding the sheet resistance of the adjacent MR ELGs 42. There are many circuits for performing this type of calibration of the sheet resistance known in the prior art.

The relationship between the overall resistance, R, of the MR element 43 and the change in resistance, ΔR, is critical to obtaining a MR sensor 32 with an acceptably high signal-to-noise ratio. Therefore, the process of making MR sensors 32 for disk drive sliders 36 starts with elements 43 having initial heights, Hi, that are too large. A diamond lapping process then is used to lap away the surface 40 of a row 37, while ELGs 42 with MR elements 64 of the same material and thickness as the MR elements 43, are used to electrically monitor the lapping process as the surface 40 is being lapped in the direction of arrow 66 to assure that useful MR sensors 32 are produced each having final heights H_f in an acceptable range. The acceptable range is becoming smaller continuously. The MR element 43 so formed acts as a variable impedance when impinged upon by a magnetic field 60.

The prior art processes taught in U.S. Pat. Nos. 5,607,340 and 5,620,356 use two or more ELGs 42 formed on a row 37 of about 20 sliders, which are all lapped at the same time by bonding the slider row 37 on a row bending tool 70, as shown in FIG. 6. The slider row 37, with its MR elements 43 and ELG elements 64, is lapped while the lapping process is monitored by the ELGs 42. The row bending tool 70 is held by two mounting holes 72 and 74 while its face 76 and the row 37 bonded thereto are bent into up to fourth order curves in the vertical plane parallel to the tool 70 by applying forces to bending connections 78, 80, and 82. As the tolerances for the MR elements 43 get tighter, the curvature of the row 37 caused by the process steps at the wafer stage, causes inaccuracies that can not be accommodated by the tool 70.

In the present invention, a straight ceramic or steel row carrier 84 with a rectilinear cross-section and preferably an optically flat surface 86 and a parallel surface 88 is constructed. Suitable materials for the row carrier 84 include ceramic, steel, or other materials that have suitable flexibility and thermal expansion characteristics. Generally the material of the row carrier 84 should be relatively stiff and have a temperature expansion coefficient similar to that of the wafer 30 from which the row 37 is constructed. As shown in FIG. 8, the under surface 90 of the row 37 is bonded to the flat surface 86 with the surface 48 to be lapped generally parallel to the surface 86. Although the row carrier 84 is may be physically larger and stiffer than the row 37, when dealing in microinches, bonding a row 37 that is curved because of residual stresses to the row carrier 84 can cause some deflection of the row and row carrier assembly 92. This deflection is shown as causing a smooth curve in FIG. 8, however prior art data scatter indicates that unpredictable kinks are present. Therefore, once the assembly 92 is formed, the kerf areas 38 are diced away. As shown in FIG. 9, the removal of material may extend through the bonding agent 94 and into the row carrier 84. This greatly relieves the residual stresses and allows the assembly 92 to return to a flatness, suitable for lapping sliders 36 down to 5% sliders. To allow such kerf area removal, the ELGs 42, if used, are formed on empty real estate at the rear surface 46 of two or more sliders 36 in the row 37.

FIG. 10 is a partial cross-sectional view of the assembly 92 of FIG. 9 showing the material 96 added to the wafer 30 to form the electrically operative portions of the sliders 36 and the original width of the wafer 30 (arrow 98). Since sliders 36 sized below 30% have very little surface 48 to lap, the surface 48 may become unstable during lapping. Also the very thin wafers 30 needed to make below 30% sliders 36 are difficult to process. Therefore, the sliders 36 of the present invention are usually constructed from wafers 30 thicker than they need to be to provide sufficient length to the sliders 36. As can be seen, the extra thickness or waste 100 is sliced apart from the sliders 36 by the parting area 102, but may be retained on the row carrier 84 to help

stabilize the row of sliders 36 during the lapping process. Usually process steps are saved if the waste 100 is diced at the same time that the kerf areas 38 are removed. Since the kerf areas 38 are removed before the lapping process, the ELGs 42 are formed adjacent the MR sensors 32 on the sliders 36 in the material 96, or MR elements 43 may be used with the proper stimulation and measurement techniques.

The assembly 92, with the sliders 36 and the waste blocks 100, each bonded to separate surfaces 103 and 104 of the surface 86, is then bonded to the face 76 of a row bending tool 70, and the lapping process is performed, while differences in MR element resistance are accommodated by bending the row 37 during lapping so the MR element resistance of the MR sensor of each slider 36 falls within an optimum range.

As the demands for precision continue, some processes can not make MR elements precise enough to be controllably lapped using the fourth order curve bending technology discussed above. The present invention can accommodate control of much smaller groups of sliders in the row or even control of the lapping of individual sliders as shown in FIGS. 12, 13, and 14.

FIG. 12 is a partial cross-sectional view of a modified assembly 92' with the extra thickness or waste 100 at least partly ground away after it is sliced apart from the sliders 36 by the parting area 102. This allows material 120 to be removed from the slider 36 quickly during the lapping process so that the slider can be formed with a slightly curved slider surface 40. If the waste 100 is not removed, then longer lapping time can be expected. In the assembly 96', the row carrier 84' preferably is constructed from steel or other material that is not brittle like ceramic. As shown in FIG. 12, the removal of material extends almost completely through the row carrier 84', which also may be thinner than row carrier 86. This relieves the residual stresses and allows the sliders 36 in the assembly 92' to be moved individually, since the remaining areas of the row carrier 84' act like flexures. The slots 122 can also be formed in advance wider than the spacing between the diced sliders 36, although then some longitudinal alignment is required to align the slots 122 with the kerf areas 38.

The assembly 92' is then bonded to the fingers 124 of a lapping pressure applying fixture 126. Generally each of the fingers 124 are attached to a voice coil which levers them to apply more or less pressure when the row 37 is being lapped. This method requires a control device (either an ELG or the MR element itself) on each slider or small group of sliders when two or more sliders are attached to each finger 124, to be sensed during the lapping process. The lapping process is performed, while differences in MR element resistance are accommodated by bending the row carrier 84' during lapping so the MR element resistance of the MR sensor 32 of each slider 36 falls within an optimum range. The displacement between fingers 122 is just a Lew millionths of an inch, so the flexures 126 need not accommodate much travel. As shown in FIG. 15, each finger 126 may force more than one slider 36 into the proper lapping position or remove lapping force while an adjacent pair of sliders 36 are still being lapped on the lapping plate 128, only portions of which are shown.

FIG. 16 illustrates a possible alignment method for the row 37 on the row carrier 92' to assure parallel alignment there between when they are bonded together, the surface 134 that was the under surface of the wafer and the back surface of the row carrier being held against the flat surface 138 of a hard stop 140.

Thus there have been shown and described novel processes and apparatus that fulfill all the objects and advantages sought therefor. Many changes, modifications, variations, uses and applications of the subject invention will however become apparent to those skilled in the art after considering the specification and the accompanying drawings. All such changes, modifications, alterations and other uses and applications which do not depart from the spirit and scope of the invention are deemed to be covered by the invention, which is limited only by the claims that follow.

What is claimed is:

1. A process in the manufacture of disk drive sliders with read and write devices from a wafer on which a plurality of magneto-resistive read sensor blanks and write device blanks have been formed on a first surface of the wafer in rows, the first surface to become the back surfaces of the sliders formed therefrom, including:

cutting the wafer perpendicular to the first surface into rows, each row containing a plurality of slider blanks with at least one write and read sensor blank on each slider blank so each row has generally parallel second and third surfaces generally perpendicular to the first surface, with the write and read blanks facing the second surface;

mounting the third surface of a row to a first flat surface of a row carrier tool having an opposite second surface generally parallel to the first flat surface for mounting to a row bending tool;

dicing each row into separate slider blanks to relieve residual stresses therein; and

lapping the second surfaces of the slider blanks to trim the magneto-resistive elements of the read sensors and to form the slider surfaces that fly over the disk of the disk drive.

2. The process as defined in claim 1 wherein said mounting of the third surface of the row to the first flat surface of the row carrier includes:

releasably bonding the third surface of the row to the first flat surface of the row carrier.

3. The process as defined in claim 1 wherein after said mounting of the third surface of a row to a first flat surface of a row carrier, further including:

cutting the slider blanks generally parallel to the first slider surface to reduce the size of the second and third surfaces and create waste blocks.

4. The process as defined in claim 3 further including:

removing at least portions of the waste blocks from the row carrier tool prior to said lapping of the second surfaces of the slider blanks to trim the magneto-resistive elements of the read sensors.

5. The process as defined in claim 3 wherein said dicing each row into separate slider blanks to relieve residual stresses therein includes:

cutting into the row carrier.

6. The process as defined in claim 5 wherein an electrical lapping guide was formed on the first surface of each slider blank of the wafer when the magneto-resistive sensors were formed, wherein said dicing of each row carrier into slider blanks includes:

dicing the row carriers without cutting into the electrical lapping guides, the write device blanks, or the magneto-resistive read sensor blanks.

7. The process as defined in claim 5 wherein said cutting into the row carrier includes:

cutting almost completely through the row carrier to form a flexure between adjacent sliders.

8. The process as defined in claim **7** wherein a plurality of flexures are formed by said cutting almost completely through the row carrier to form a flexure between adjacent sliders and said lapping of the second surfaces of the slider blanks to trim magneto-resistive read sensor blanks include:

mounting the second surface of the row carrier between flexures to individual fingers of a row bending fixture; and

bending the row carrier at the flexures so that said lapping can form precise magneto-resistive read sensors when the magneto-resistive read sensor blanks are not consistently formed.

9. The process as defined in claim **7** wherein the row carrier is constructed from steel.

10. The process as defined in claim **1** wherein an electrical lapping guide was formed on the first surface of at least some of the slider blanks of the wafer when the magneto-resistive sensors were formed, wherein said dicing of each row carrier into slider blanks includes:

dicing the row carriers without cutting into the electrical lapping guides, the write device blanks, or the magneto-resistive read sensor blanks.

11. The process as defined in claim **10** wherein after said mounting of the third surface of a row to a first flat surface of a row carrier, further including:

cutting the slider blanks generally parallel to the first slider surface to reduce the size of the second and third surfaces and create waste blocks.

12. The process as defined in claim **11** further including:

removing at least portions of the waste blocks from the row carrier tool prior to said lapping of the second surfaces of the slider blanks to trim the magneto-resistive elements of the read sensors.

13. The process as defined in claim **1** wherein said lapping of the second surfaces of the slider blanks to trim magneto-resistive read sensor blanks include:

mounting the second surface of the row carrier to a row bending tool; and

bending the row carrier in up to a fourth order curve so that said lapping can form precise magneto-resistive read sensors when the magneto-resistive read sensor blanks are not consistently formed.

14. The process as defined in claim **1** wherein said lapping of the second surfaces of the slider blanks to trim magneto-resistive read sensor blanks include:

mounting the second surface of the row carrier to individual fingers of a row bending fixture with at least one slider blank positioned in alignment with each finger; and

bending the row carrier by applying lapping pressure through the fingers so that said lapping can form precise magneto-resistive read sensors when the magneto-resistive read sensor blanks are not consistently formed.

15. The process as defined in claim **1** wherein after said lapping the second surfaces of the slider blanks to trim the magneto-resistive elements of the read sensors, further including:

cutting the slider blanks generally parallel to the first slider surface to reduce the size of the second and third surfaces.

16. A process in the manufacture of disk drive sliders with read and write devices from a wafer on which a plurality of magneto-resistive read sensor blanks and a plurality of write device blanks have been formed on a first surface of the wafer in rows, the first surface to become the back surfaces of the sliders formed therefrom, including:

cutting the wafer perpendicular to the first surface into rows, each row containing a plurality of slider blanks with at least one write and read sensor blank on each slider blank, the cutting being so each row has generally parallel second and third surfaces generally perpendicular to the first surface, with the write and read blanks facing the second surface;

mounting the third surface of a row to a first flat surface of a row carrier tool having an opposite second surface generally parallel to the first flat surface for mounting to a row bending tool;

lapping the second surfaces of the slider blanks to trim the magneto-resistive elements of the read sensors and to form the slider surfaces that fly over the disk of the disk drive, and at some time during the fabrication of the sliders,

dicing each row into separate slider blanks to relieve residual stresses therein.

17. The process as defined in claim **16** wherein said mounting of the third surface of the row to the first flat surface of the row carrier includes:

releasably bonding the third surface of the row to the first flat surface of the row carrier.

18. The process as defined in claim **16** wherein the row carrier is constructed from heat conducting material.

* * * * *

United States Patent [19]
Hamakawa et al.

[11] **Patent Number:** **4,814,921**
[45] **Date of Patent:** **Mar. 21, 1989**

[54] **MULTILAYERED MAGNETIC FILMS AND THIN-FILM MAGNETIC HEADS USING THE SAME AS A POLE**

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[73] Assignee: **Hitachi, Ltd.**, Tokyo, Japan

[21] Appl. No.: **150,504**

[22] Filed: **Feb. 1, 1988**

Related U.S. Application Data

[63] Continuation of Ser. No. 788,561, Oct. 17, 1985, abandoned.

[30] **Foreign Application Priority Data**

Oct. 17, 1984	[JP]	Japan	59-216143
Feb. 15, 1985	[JP]	Japan	59-26227
Mar. 25, 1985	[JP]	Japan	59-58295

[51] **Int. Cl.**^{4} **G11B 5/127**
[52] **U.S. Cl.** **360/126**
[58] **Field of Search** 360/126; 428/554

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,404,609	9/1983	Jones	360/126
4,593,334	6/1986	Anderson et al.	360/126

Primary Examiner—Robert S. Tupper
Attorney, Agent, or Firm—Antonelli, Terry & Wands

[57] **ABSTRACT**

Multilayered magnetic films of the invention comprising at least two unit magnetic films each of which has a thickness of from 0.05 to 0.9 μm and includes a plurality of ferromagnetic layers each having a thickness of from 0.01 to 0.2 μm and a 1 nm to 10 nm thick first intermediate layer consisting of a ferromagnetic, nonmagnetic or antiferromagnetic material and provided between adjacent ferromagnetic layers, and a second intermediate layer having a thickness of from 10 to 40 nm, consisting of a nonmagnetic or antiferromagnetic material and provided between the at least two unit magnetic films. The multilayered magnetic film is suitable as a pole of a thin-film magnetic head. An underlayer may be further provided between the magnetic film and a substrate whereby a multilayered magnetic film having good characteristics can be obtained.

18 Claims, 9 Drawing Sheets

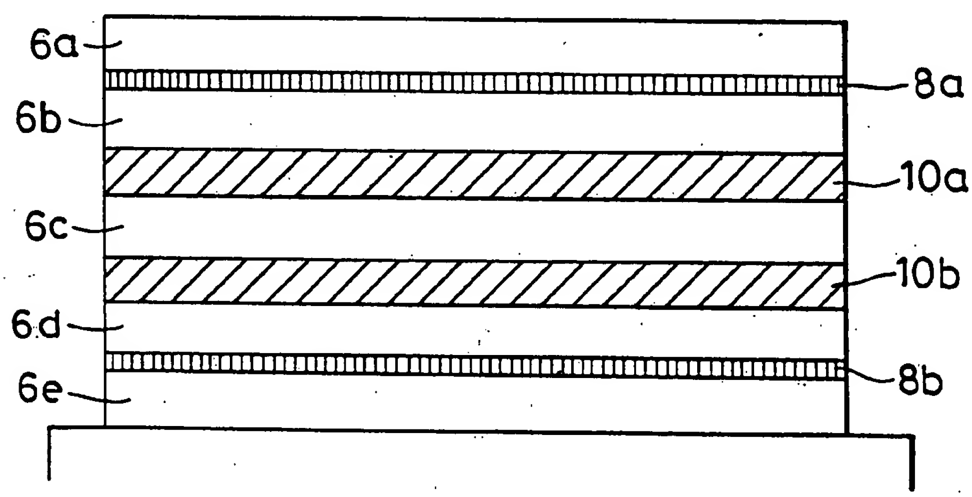


FIG. 1

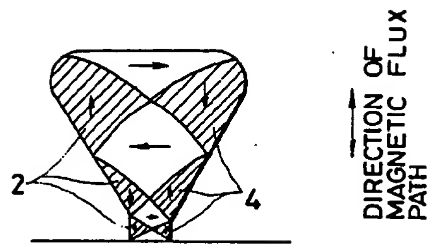

2
4
DIRECTION OF MAGNETIC FLUX PATH

FIG. 2

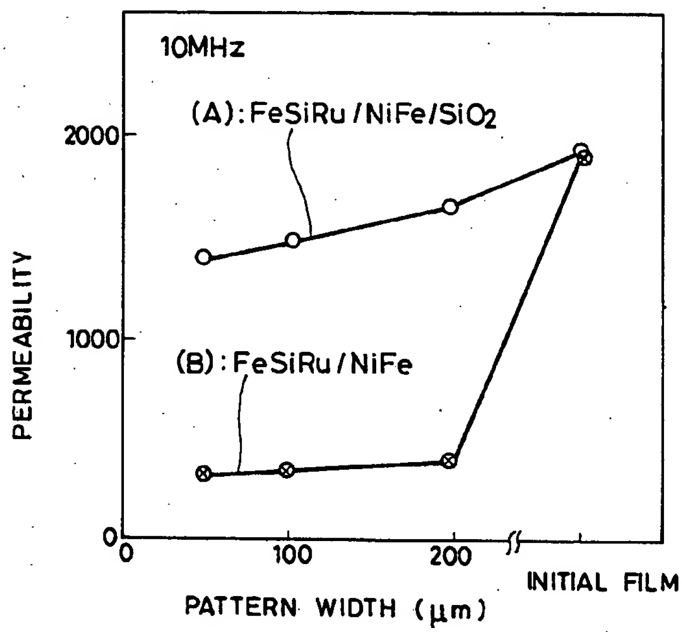
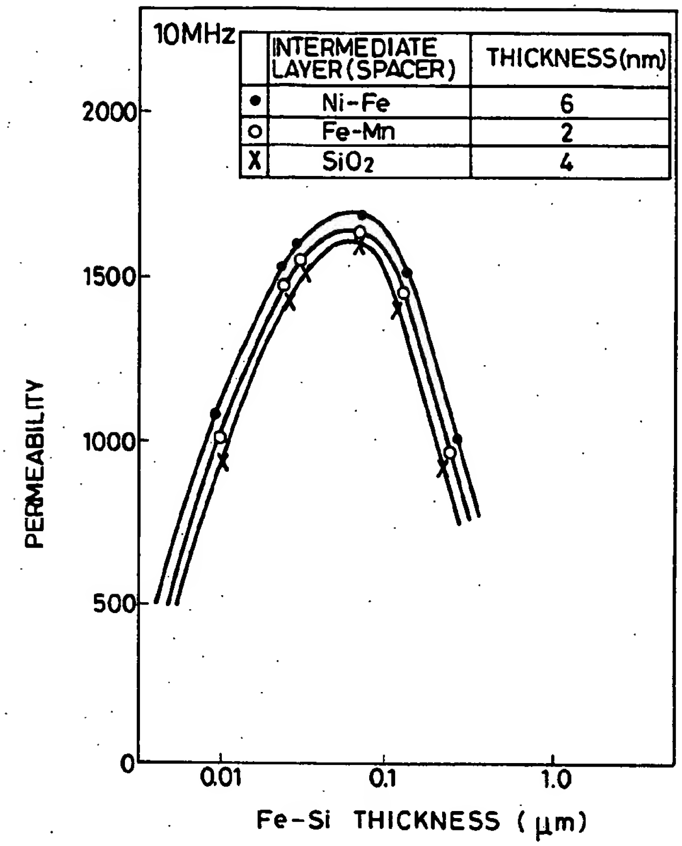

10MHz
(A): FeSiRu/NiFe/SiO2
(B): FeSiRu/NiFe
2000
1000
0
PERMEABILITY
0
100
200
INITIAL FILM
PATTERN WIDTH (μm)

FIG. 3



10MHz
INTERMEDIATE LAYER (SPACER)
THICKNESS (nm)
Ni-Fe
6
Fe-Mn
2
SiO_2
4
2000
1500
1000
500
0
PERMEABILITY
0.01
0.1
1.0
Fe-Si THICKNESS (μm)

FIG. 4

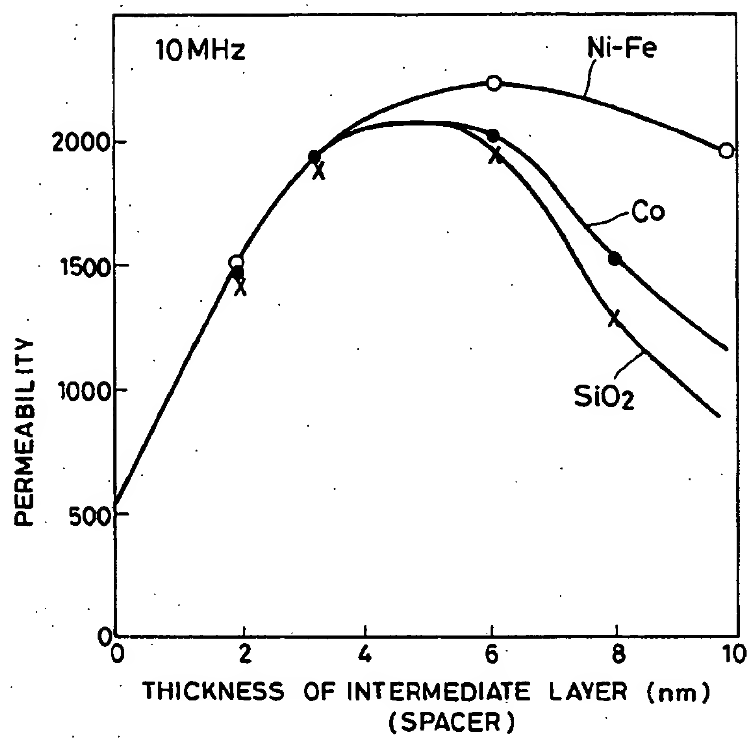

10MHz
Ni-Fe
Co
SiO2
PERMEABILITY
2000
1500
1000
500
0
0
2
4
6
8
10
THICKNESS OF INTERMEDIATE LAYER (nm)
(SPACER)

FIG. 5

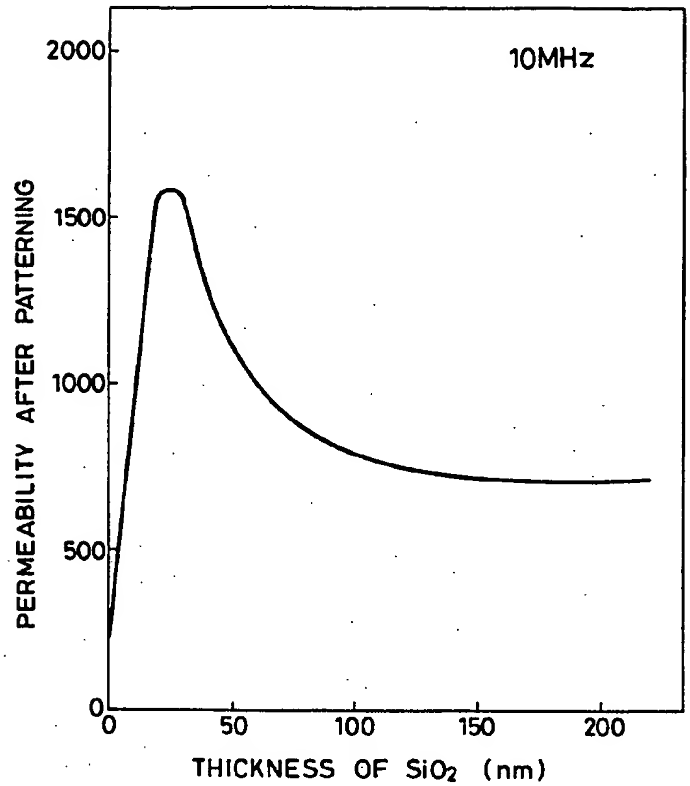

10MHz
PERMEABILITY AFTER PATTERNING
2000
1500
1000
500
0
0
50
100
150
200
THICKNESS OF SiO2 (nm)

FIG. 6

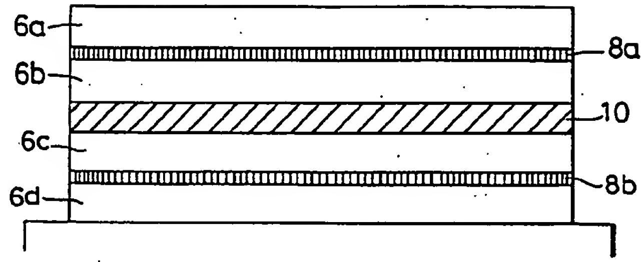


FIG. 7

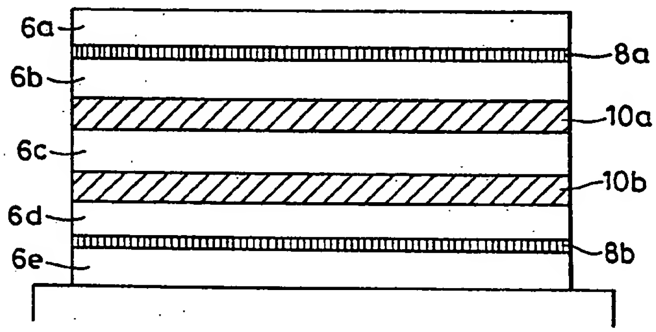


FIG. 8(a)

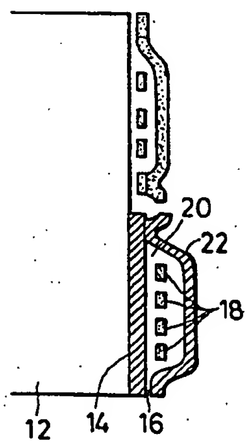


FIG. 8(b)

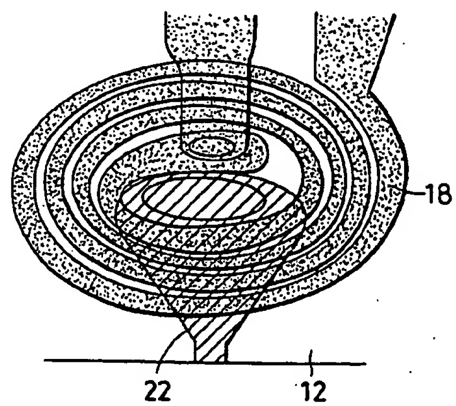


FIG. 9

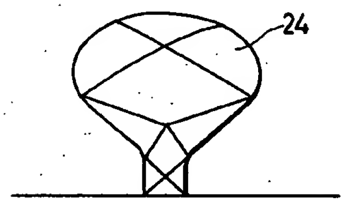


FIG. 10

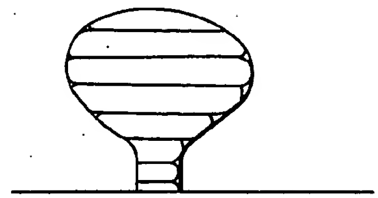


FIG. 11

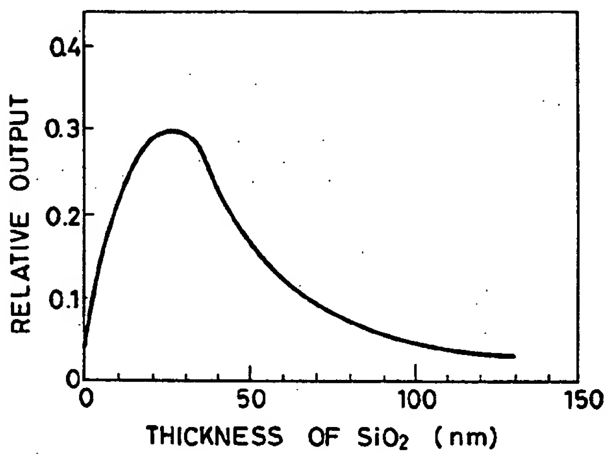


FIG. 12

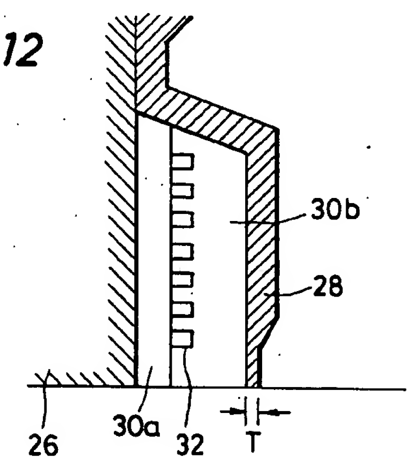


FIG. 13

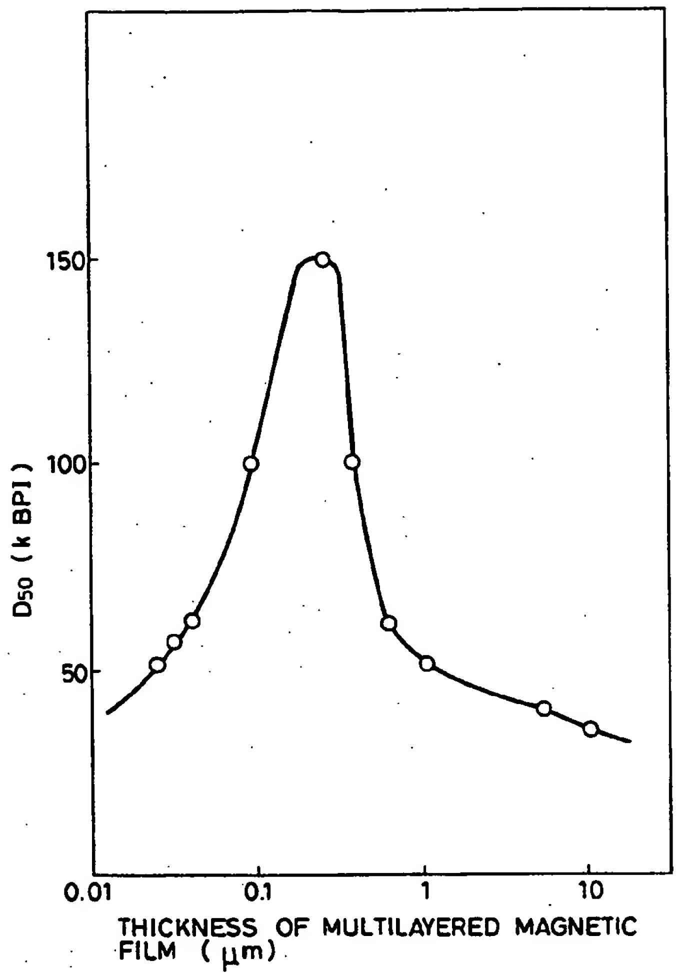

150
100
50
D50 (k BPI)
0.01
0.1
1
10
THICKNESS OF MULTILAYERED MAGNETIC FILM (μm)

FIG. 14

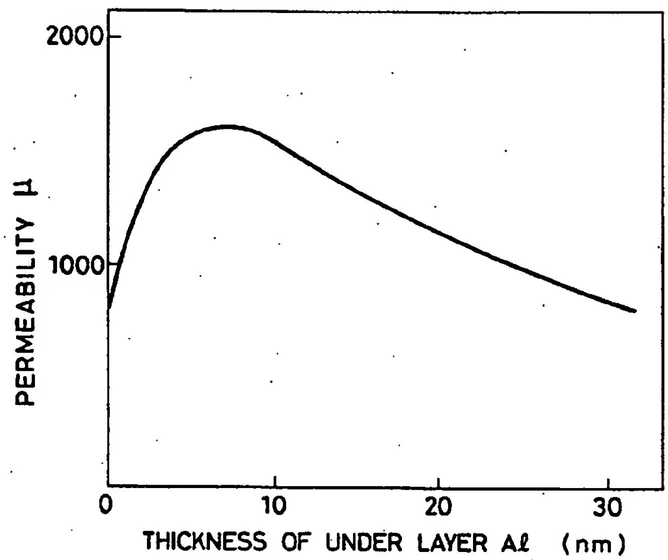


FIG. 15(a)

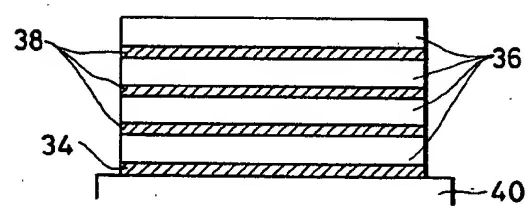


FIG. 15(b)

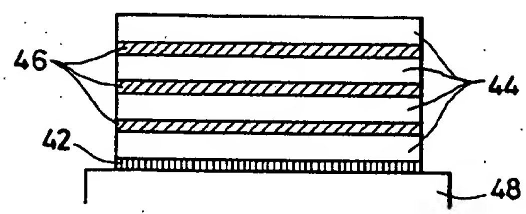


FIG. 16

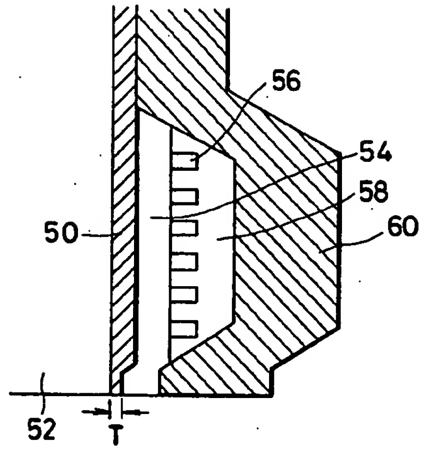
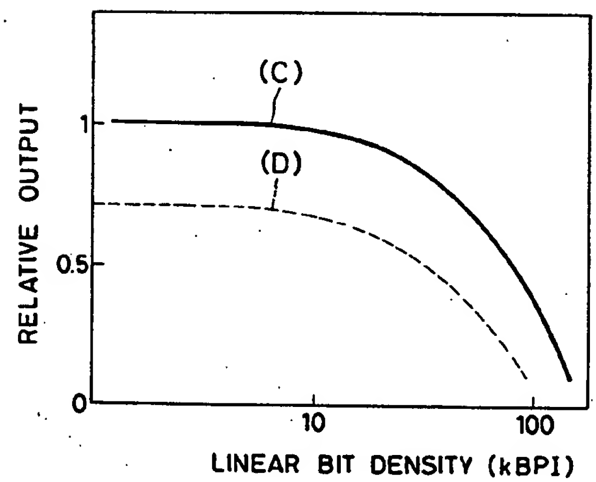

56
54
58
60
50
52
T

FIG. 17


(C)
(D)
RELATIVE OUTPUT
1
0.5
0
10
100
LINEAR BIT DENSITY (kBPI)

MULTILAYERED MAGNETIC FILMS AND THIN-FILM MAGNETIC HEADS USING THE SAME AS A POLE

This application is a continuation of application Ser. No. 788,561, filed Oct. 17, 1985, now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to magnetic films having a high permeability in a high frequency range and a low coercive force and more particularly, to multilayered magnetic films which can maintain a high permeability even when processed in the form of a pole and have good magnetic characteristics. The invention also relates to high performance thin-film magnetic heads using the multilayered magnetic films.

2. Description of the Prior Art

For the improvement of high frequency characteristics of magnetic films, there is known a method in which magnetic layers are deposited through a nonmagnetic intermediate layer such as SiO_2. As particularly described in Japanese Laid-open Patent Publication No. 58-192311, it is known that with known multilayered magnetic films such as, for example, a multilayered magnetic film in which Fe-Si layers are superposed through an intermediate layer of a nonmagnetic material such as SiO_2, the grain size of Fe-Si itself becomes smaller by the superposition, so that the dispersion of the anisotropy is suppressed, leading to an improvement of magnetic characteristics of the resultant film. In this case, the thickness is generally in the range of from 0.01 to 0.2 μm for the magnetic films and in the range of from 1 nm to 10 nm for the intermediate layer. This is because when the thickness of the intermediate layer is in the order of several nm, pin holes are essentially present, so that the exchange interaction between the Fe-Si layers are induced through the pin holes and thus the respective layers couple ferromagnetically while suppressing the dispersion of the anisotropy. As a consequence, the film has good magnetic characteristics as a whole.

On the other hand, in order to improve the high frequency characteristics of the multilayered magnetic films, it is necessary to reduce an eddy current loss in the high frequency range. In Japanese Laid-open Patent Publication No. 59-9905 (1984), an attempt was made to improve the high frequency characteristics of the multilayered film by superposing the magnetic layers through a thicker nonmagnetic insulative layer. For improving the high frequency characteristics, it is stated to be desirable that the thickness of the nonmagnetic intermediate layer ranges from 0.05 to 1 μm. However, when such multilayered film is patterned in the form of a pole for application to a thin-film magnetic head, the permeability at 10 MHz lowers to about 1/10 time the permeability of the initial film prior to the patterning. Thus, good head characteristics cannot be obtained.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide multilayered magnetic films which overcome the above prior problems and have a high permeability in a high frequency range with a low coercive force.

It is another object of the invention to provide a thin-film magnetic head which makes use of the above-mentioned multilayered magnetic film as a pole.

The present invention is accomplished based on the following findings.

In known multilayered magnetic films, the individual layers couple ferromagnetically, so that the direction of magnetization cannot be changed along the film thickness. When this type of multilayered magnetic film is applied to a thin-film magnetic head and patterned in the form of a magnetic core, the influence of the demagnetizing field at the end of the core is reduced, so that the direction of magnetization in the plane is controlled. On observation of the Bitter pattern at the pole, a triangular magnetic domain as shown in FIG. 1 is formed, causing the pole not to be formed at the end of the magnetic core. Within the inside of the triangular magnetic domain, the axis of easy magnetization is turned toward the direction of the magnetic flux path of the magnetic core. Especially, when the core is energized at a high frequency or a record signal is read, the response in the inside becomes slow, with the result that an effective permeability lowers as a whole of the pole. Thus, the recording and reproducing characteristics of the head apparently lower.

The above phenomenon becomes more pronounced at a larger saturation flux density Bs of a magnetic material and thus presents a more serious problem.

We made extensive studies of various film structures and theoretical analyses in order to solve the above problem. As a result, we succeeded in making multilayered films of magnetic materials having a high Bs value, which has good permeability even after patterning. In order to improve magnetic characteristics of a ferromagnetic thin film after patterning, at least two unit magnetic films in which ferromagnetic material layers are superposed through an intermediate layer, are further superposed through a different intermediate laer having a thickness of 10 nm to 40 nm. The at least two intermediate layers should preferably consist of different types of materials including ferromagnetic, nonmagnetic and antiferromagnetic materials. Since the unit magnetic films are further superposed through the second intermediate layer, the permeability does not deteriorate even after processing the film into a finer pattern. As described in IEEE Trans., Magn., Vol. 1, Mag-13, pp. 1521-1523, Ni-Fe magnetic films are superposed through a 10 nm thick intermediate layer of Cu with similar results. In the practice of the invention, however, the intermediate layers are made of at least two different types of materials, so that the effect becomes more pronounced than in the prior art case.

FIG. 2 shows the results of a comparison between a magnetic film having two different intermediate layers and a magnetic film having only one intermediate layer with respect to permeability. FIG. 2 shows the relation between the permeability and the pattern width, in which the curves A and B are, respectively, for unit magnetic films which comprise a five-layered magnetic film having 0.1 μm thick 7 wt% Si-Fe layers and 3 nm thick first intermediate layers having a thickness of 3 nm. The magnetic materials may be, instead of Si-Fe, Co-Fe, Fe-Ti, Co-Zr or Co-ZrMo. The first intermediate layer may be made of ferromagnetic materials such as Ni, Fe, Co and Fe_2O_3, or antiferromagentic materials such as NiO, Mn-Fe and the like, with similar results. The Fe-Si magnetic material layer should preferably have a thickness of from 0.01 to 0.2 μm, more preferablyfrom 0.04 to 0.12 μm, as shown in FIG. 3. This is because if the magnetic film thickness is less than 0.01 μm, the magnetic characteristics such as thermal stress

tend to deteriorate. On the other hand, when the thickness exceeds 0.2 μm, the grain size undesirably increases and thus the magnetic characteristics deteriorate. The unit magnetic films are superposed through a second intermediate layer of SiO_2 having a thickness of 20 nm. Similar results are obtained when there are used, instead of SiO_2, Al_2O_3, Ti, Mo, W and the like. The thickness of the first intermediate layer is in the range of from 1 to 10 nm, preferably from 2 to 8 nm as will be seen from FIG. 4. This is because when the thickness is less than 1 nm, the quality of the intermediate layer is poor and the crystal grains grow through the pin holes, so that the magnetic characteristics deteriorate. On the other hand, when the thickness exceeds 10 nm, the magnetization of the respective magnetic layers is reversed, so that magnetic characteristics deteriorate. Moreover, the second intermediate layer has generally a thickness of from 10 to 40 nm, preferably from 15 to 30 nm, as will be seen from FIG. 5. When the thickness is less than 10 nm, the interaction between the respective unit magnetic layers is so strong that the directions of magnetization of the respective layers become the same, thus leading to deterioration of magnetic characteristics after patterning.

As will be seen from the above, the directions of magnetization of adjacent unit ferrogmagnetic layers or films of the multilayered magnetic film according to the invention are opposite to each other. Even though a free pole is produced at the end of the magnetic core, a free pole of a opposite polarity exists near the core end, so that an increase of magnetostatic energy is very small. Accordingly, it is unnecessary to form triangular magnetic domains 2,4 shown in FIG. 1. This effect is more remarkable when the total of unit magnetic films is an even number for the same thickness on taking the compensating effect of the free pole into consideration. In this manner, the deterioration of magnetic characteristics can be prevented as shown in FIG. 2 even when the magnetic film is shaped into a magnetic core form.

As will be appreciated from the foregoing, the above effect becomes greater on a magnetic film making use of a ferromagnetic material which tends to form a magnetic domain structure by paterning and whose saturation magntic flux density is not less than 1.2 T, preferably not less than 1.5 T. This becomes more remarkable when the thickness of the unit magnetic film is in the range of from 0.05 to 0.9 μm, preferably 0.09 to 0.2 μm. In view of the reproducibility and reliability, it is preferred to use Fe-Si or Fe-Si-Ru as the ferromagnetic material, Ni-Fe alloy as the first intermediate layer, and SiO_2 or Al_2O_3 as the second intermediate layer.

The multilayered films of the invention have good magnetic characteristics when patterned in the form of a pole. The thin-film magnetic head using the film has much better characteristics by at least two times than thin-film heads of other constructions. Especially, when the multilayered film is used as a main pole of the thin-film head, this head is very suitable as a head for vertical magnetic recording since the magnetic characteristics of the thin film do not deteriorate.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a magnetic domain pattern of a known multilayered magnetic film which has been patterned in the form of a pole;

FIG. 2 is a graphical representation of the relation between permeability and pattern width of a multilayered film, after being patterned in the form of a pole, of the invention in comparison with a known multilayered film;

FIG. 3 is a graphical representation of the thickness dependence of permeability of a multilayered magnetic film of the invention;

FIG. 4 is a graphical representation of the dependence of permeability on the thickness of a first intermediate layer in a multilayered magnetic film acccording to the invention;

FIG. 5 is a graphical representation of the dependence of permeability of a multilayered magnetic film of the invention on the thickness of a second intermediate layer;

FIGS. 6 and 7 are, respective, schemative views of multilayered magnetic films according to the invention;

FIGS. 8a and b is a schematic sectional view of a thin-film magnetic head in which a multilayered magnetic film of the invention is applied as a pole;

FIGS. 9 and 10 are, respectively, schematic views of triangular magnetic domains in cases where the thicknesses of a second intermediate layer are 0.5 nm and 10 nm or over, respectively;

FIG. 11 is a graphical representation of the relation between thickness of an SiO_2 intermediate layer and relative output;

FIG. 12 is a schematic sectional view of a thin-film magnetic head using a multilayered magnetic film of the invention;

FIG. 13 is a graphical representation of the relation between thickness of a multilayered film of the invention and recording density characteristic;

FIG. 14 is a graphical representation of the relation between thickness of an Al underlayer and permeability;

FIGS. 15a and b are sectional views illustrating a multilayered magnetic film of the invention in which an underlayer is provided between a substrate and the magnetic film;

FIG. 16 is a schematic sectional view of a thin-film magnetic head using the multilayered magnetic film of the invention as a main pole; and

FIG. 17 is a graphical representation of the relation between linear bit density and relative output in cases where an underlayer is present and absent.

DETAILED DESCRIPTION AND PREFERRED EMBODIMENTS OF THE INVENTION

Reference is now made to FIG. 6, which shows one embodiment of a multilayer structure of a multilayered magnetic film of the invention. The multilayered magnetic film includes main magnetic material layers 6a, 6b, 6c, 6d, first intermediate layers 8a, 8b keeping ferromagnetic coupling between the respective main magnetic material layers, and a second intermediate layer 10 prohibting the ferromagnetic coupling between the main magnetic layer halves. The main magnetic materials for the layers 6a, 6b, 6c, 6d, which have a high saturation magnetic flux density, include Fe-Si alloys, Fe-Ge alloys, Fe-Ti alloys, Fe-N alloys, Co-Fe alloys Co-Zr alloys, Co-Ti alloys, Co-Ta alloys and the like. From the standpoint of the saturation magnetic flux density, Fe-base alloys are preferred. The first intermediate layers 8a, 8b may be made of ferromagnetic materials such as Ni-Fe alloys, Co and the like, non-magnetic materials such as SiO_2, Al_2O_3, Al, Ti, Mo and the like, and antiferromagnetic materials such as Fe-Mn alloys. Particular examples of the magnetic layer and the first intermediate layer are shown in Table 1. These layers

may be formed by sputtering, vacuum deposition or the like techniques, When the intermediate layer is formed of a non-magnetic material, the magnetic layer may be oxidized on the surface thereof by introducing oxygen into a sputtering apparatus.

TABLE 1-1

	(1) Thickness (μm)	Material	(2) Thickness (μm)	Material	(3) Thickness (μm)	Material
			Magnetic Layer:			
11	0.05	Fe—6%Si—1%Ru	0.1	Fe—8%Si—2%Ru	0.07	Fe—7%Si—3%Ru
12	0.05	Fe—6%Si—1%Ru	0.05	Fe—8%Si—2%Ru	0.1	Fe—7%Si—3%Ru
13	0.05	Fe—6%Si—1%Ru	0.05	Fe—8%Si—2%Ru	0.07	Fe—7%Si—3%Ru
14	0.05	Fe—6%Si—1%Ru	0.1	Fe—8%Si—2%Ru	0.1	Fe—7%Si—3%Ru
			Intermediate Layer:			
15	0.05	Ni—20%Fe	0.006	Ni—17%Fe	0.003	Co
16	0.05	Ni—20%Fe	0.004	Ni—17%Fe	0.005	Co
17	0.02	SiO_2	0.03	Al_2O_3	0.015	SiO_2

TABLE 1-2

	(4) Thickness (μm)	Material	(5) Thickness (μm)	Material	(6) Thickness (μm)	Material
			Magnetic Layer:			
11	0.04	Fe—8%Si—5%Ru	0.4	Fe—7%Si—8%Ru	0.04	Fe—5%Si—15%Ru
12	0.06	Fe—8%Si—5%Ru	0.4	Fe—7%Si—8%Ru	0.04	Fe—5%Si—15%Ru
13	0.04	Fe—8%Si—5%Ru	0.5	Fe—7%Si—8%Ru	0.04	Fe—5%Si—15%Ru
14	0.06	Fe—8%Si—5%Ru	0.5	Fe—7%Si—8%Ru	0.15	Fe—5%Si—15%Ru
			Intermediate Layer:			
15	0.003	Ni—18.5%Fe	0.003	SiO_2	0.003	Fe—Mn
16	0.003	Ni—18.5%Fe	0.003	SiO_2	0.003	Fe—Mn
17	0.020	Ti	0.005	Fe—Mn	0.02	SiO_2

The thicknesses of the main magnetic material layers *6a, 6b, 6c, 6d* should preferably be in the range of from 0.01 μm to 0.2 μm, most preferably from 0.04 to 0.12 μm, in which a smaller grain size can be achieved. As described before, the thickness of the first intermediate layers *8a, 8b* should preferably be in the range of from 1 to 10 nm, most preferably from 2 to 8 nm, in order to ensure good ferromagnetic coupling of the magnetic layers through the intermediate layer. When a nonmagentic film is used as the first intermediate layers *8a, 8b*, it is preferred to make a smaller thickness than in the case using a magnetic film. The thickness of the second intermediate layer **18** should preferably be larger than the first intermediate layers *8a, 8b* in order to cut off the ferromagnetic coupling between the magnetic films formed through the second layer **18**. In this sense, the thickness is preferably in the range of from 10 to 40 nm, most preferably from 15 to 30 nm.

When the unit magnetic film including two magnetic films and the first intermediate layer *8a* or *8b* formed between the magnetic films, is too thick, an adverse influence of the demagnetizing field appears. To avoid this, the thickness is preferably in the range of from 0.05 to 0.9 μm, most preferably from 0.09 to 0.2 μm.

The number of the unit magnetic films is preferred to be even as shown in FIG. 6. However, an odd number of the unit magnetic film may be used as in FIG. 7.

In Table ;b 2, there are shown further examples of the magnetic layer and the intermediate layer.

TABLE 2-1

	(1) Thickness (μm)	Material	(2) Thickness (μm)	Material	(3) Thickness (μm)	Material
			Magnetic Layer:			
21	0.05	Fe—6%Si—1%Ru	0.1	Fe—8%Si—2%Ru	0.07	Fe—7%Si—3%Ru
22	0.05	Fe—6%Si—1%Ru	0.05	Fe—8%Si—2%Ru	0.07	Fe—7%Si—3%Ru
23	0.05	Fe—6%Si—1%Ru	0.05	Fe—8%Si—2%Ru	0.1	Fe—7%Si—3%Ru
24	0.05	Fe—6%Si—1%Ru	0.05	Fe—8%Si—2%Ru	0.07	Fe—7%Si—3%Ru
25	0.05	Fe—6%Si—1%Ru	0.1	Fe—8%Si—2%Ru	0,1	Fe—7%Si—3%Ru
			Intermediate Layer:			
26	0.005	Ni—20%Fe	0.003	Ni—17%Fe	0.003	Co
27	0.03	SiO_2	0.003	Fe—Mn	0.03	SiO_2
28	0.03	SiO_2	0.02	Fe—Mn	0.015	SiO_2
29	0.005	Ni—20%Fe	0.005	Ni—17%Fe	0.003	Co

TABLE 2-2

	(4) Thickness (μm)	Material	(5) Thickness (μm)	Material	(6) Thickness (μm)	Material
			Magnetic Layer:			
21	0.04	Fe—8%Si—5%Ru	0.08	Fe—7%Si—8%Ru	0.04	Fe—5%Si—15%Ru
22	0.06	Fe—8%Si—5%Ru	0.05	Fe—7%Si—8%Ru	0.05	Fe—5%Si—15%Ru
23	0.04	Fe—8%Si—5%Ru	0.07	Fe—7%Si—8%Ru	0.05	Fe—5%Si—15%Ru

TABLE 2-2-continued

	(4) Thickness (μm)	Material	(5) Thickness (μm)	Material	(6) Thickness (μm)	Material
24	0.06	Fe—8%Si—5%Ru	0.07	Fe—7%Si—8%Ru	0.05	Fe—5%Si—15%Ru
25	0.08	Fe—8%Si—5%Ru	0.05	Fe—7%Si—8%Ru	0.15	Fe—5%Si—15%Ru
			Intermediate Layer:			
26	0.005	Ni—18.5%Fe	0.003	SiO_2	0.002	Fe—Mn
27	0.03	Mo	0.03	Fe—Mo	0.02	Al_2O_3
28	0.04	Mo	0.02	Fe—Mn	0.03	Al_2O_3
29	0.003	Ni—18.5%Fe	0.003	SiO_2	0.002	Fe—Mn

Embodiments of thin-film magnetic heads which are fabricated by the use of the multilayered magnetic films according to the invention, ae described in detail.

Multilayered magnetic films of such a structure a shown in FIG. 6 are fabricated in which the main material having a high saturation magnetic flux density used is a Fe-6.5 wt%Si-1 wt%Ru alloy. The first intermediate layer for ferromagnetically coupling the alloy layers consists of Ni-20 wt%Fe, and SiO_2 is used as a second nonmagnetic layer for cutting off the ferromagnetic coupling between the ferromagnetic layers. The Fe-6.5 wt%Si-1 wt%Ru alloy layers are set to have a constant thickness of 0.05 μm and the Ni-20 wt%Fe alloy layers have a constant thickness of 5 nm. However, the thickness of the SiO_2 layer is changed as 0, 5, 10, 50, 90, 100 and 150 nm. These multilayered magnetic films are used to make a thin-film magnetic head of the type shown in FIG. 8. In the figure, the magnetic head includes a nonmagnetic substrate **12** such as of Al_2O_5, TiC, Al_2O_3 or ZrO_3, a multilayered magnetic film **14** of the invention, a gap layer **16** consisting of Al_2O_3, SiO_2 or the like, a coil **18** of Cu, Al or the like, an insulative layer **20** such as of a polyimide resin or SiO_2, and a magnetic layer **22** such as of CoZr, Ni-Fe or the like. The layers using Fe-Si-Ru alloys, Ni-Fe alloys and SiO_2 are formed by high frequency sputtering.

When the second intermediate SiO_2 layer of the multilayered magnetic film **14** has a thickness of 0.5 nm, it gives little effect as the intermediate layer. In fact, the permeability, at 10 MHz, of the magnetic film after patterning is as low as approximately 200. Upon observation of the magnetic domain structure, it is found that a very large triangular magnetic domain **24** is formed as particularly shown in FIG. 9. On the other hand, when the thickness of the second SiO_2 intermediate layer is 10 nm or over, the effect of SiO_2 develops and the permeability is as high as 1000 to 1500. The magnetic domain structure is observed as shown in FIG. 10, in which a triangular magnetic domain is not substantially formed.

If the thickness of the second intermediate layer is too large, the magnetic characteristics of the initial film deteriorate with a reduction of permeability after patterning.

The relative output of the magentic head according to the invention is shown in FIG. 11. For this purpose, there is used a two-layered medium having a Co-Cr vertical magnetic layer which has a saturation magnetization, Ms, of 3000 emu/cc, a coercive force, Hcl, of 5000 e and a thickness, tm, of 0.2 μm and is formed on a 0.7 μm thick Co-Zr-Mo soft magnetic layer. From the figure, it will be seen that when the second intermediate layer has a thickness between 10 nm and 40 nm, good characteristics are obtained.

FIG. 12 shows another embodiment of a thin-film magnetic head using the multilayered magnetic film of the invention. The magnetic head comprises a ferromagnetic substrate **26**, a main pole **28** using the multilayered magnetic film shown in FIG. 7, a gap layer **30a** made of SiO_2, Al_2O_3 or the like, an insulative layer **30b**, and a conductive coil **32** made of Al, Cu o the like. In FIG. 13, there is shown a bit density characteristic in relation to the thickness of the multilayered magnetic film in which the thickness used is 0.02, 0.035, 0.05, 0.1, 0.3, 0.6, 1, 2, 5, and 10 μm. In this case, a two-layered medium, which has a 0.9 μm thick CoZrMo underlayer of a high permeability and a Co-Cr layer having Ms of 800 emu/cc, Hcl of 700 Oe and tm of 3 μm, is used. The results of the figure reveal that in order to increase the bit density characteristic, the total thickness is generally in the range of from 0.035 to 1 μm, preferably from 0.05 to 0.5 μm and most preferably from 0.1 to 0.4 μm. In order to prevent the magnetic saturation of the main pole, the saturation magnetic flux density should preferably be not less than 1.2 T and most preferably not less than 1.5 T. The multilayered magnetic film has a permeability of about 1500 at 10 MHz even after patterning into the main pole. Thus, the multilayered magnetic film can provide a thin-film magnetic head which has a very high reproduction sensitivity.

Thus, the multilayered magnetic film, which has such a high permeability in a high frequency range after shaping into a pole, is effectively used as a core for a thin-film magnetic head and can remarkably improve the head performance.

The above embodiments involves the first and second intermediate layers which are of different types. If different types of intermediate layers are used, different types of targets are essentially required for the formation of the film by sputtering. In this sense, if both types of intermediate layers are made of the same type of nonmagnetic material or antiferromagnetic material, the formation of the film by sputtering becomes easy.

Further embodiments of the present invention are described.

The thin-film magnetic head shown in FIG. 12 is a so-called vertical magnetic recording head, which is adapted for use in vertical magnetic recording systems. In the system, a magnetic medium having an axis of easy magnetization perpendicular to the magnetic recording medium surface is magnetically recorded in vertical directions. In this type of thin-film magnetic head, the bit density is determined depending on the thickness, T, of a soft magnetic thin film of high permeability used as the main pole **28** in FIG. 12. If the thickness, T, of the main pole decreases, the magnetic field for recording increases sharply, making it more difficult to cause recording demagnetization. As a result, a magnetic bit density increases. For instance, when a magnetic bit density is 100 kBPI, the thickness, T, of the main pole **28** should be below 0.3 μm. However, a smaller thickness, T, of the main pole results in an increase of coercive force Hc (Oe) of the magnetic thin film and a decrease

of permeability, μ, thus causing the magnetic characteristics to deteriorate. This presents the problem that the magnetic recording and reproducing sensitivity of the thin-film magnetic head abruptly decreases. One of methods for preventing the deterioration of the soft magnetic characteritics involved by the thin-film formation is described in Japanese Laid-open Patent Publication No. 58-153223 (1983). In this method, the degenerated layer produced at the initial state of the soft magnetic thin film formation is removed to prevent the deterioration. Accordingly, the method is applicable only to fabrication of a thin-film magnetic head of a specific construction. In addition, the thin-film formation process is complicated with a number of steps.

We have made studies as to why coercive force, Hc (Oe), increases and permeability, μ, decreases as the thickness of a high permeability, soft magnetic thin film decreases. As a result, it was found that this had close relation with a surface roughness of a substrate on which a soft magnetic thin film was formed, foreign matters such as dust, and thermal strain caused between the substrate and the thin film. In case where a thin film of Fe-Si or Ni-Fe alloy was formed by vacuum deposition, sputtering, electrodeposition or the like, soft magnetic materials having a columnar structure had the tendency that as the thickness of the soft magnetic thin film decreased, the size of columnar grains in the thin film increased relative to the thickness. As a result, the dispersion of in-plane anisotropy of the soft magnetic thin film increased, so that coercive force, Hc, increased and permeability, u, decreased. Thus, in order to improve the magnetic characteristic of soft magnetic thin films, it is necessary that the size of columnar grains in the thin film be as small as possible in relation to the thickness.

The principle for the formation of a soft magnetic thin film having a small size of columnar grains in this embodiment is as follows: one columnar grain is formed such that an initial stage of forming a columnar structure of the thin film, atoms flying from an evaporation source deposit on a nucleus formed by aggregation of atoms on a subtrate. Accordingly, if a larger number of nuclei are formed, a larger number of columnar grains per unit area of the thin film are produced, which in turn results in a smaller size of columnar grains. This principle is utilized in this embodiment.

When an underlayer is formed on a substrate in a thickness of several nanometers by subjecting metal or alloy to vacuum deposition or sputtering, the atoms are clustered and form a nucleus at the initial stage of formation of a soft magnetic thin film. At higher temperatures of the substrate at which a thin film of a metal or alloy in a thickness of several nanometers is formed on the subtrate, the atom clusters are more likely to aggregate separately, making it difficult to form a continuous structure. This results in an increasing number of independent nuclei and thus, a columnar grain size of the soft magnetic thin film formed on the nuclei becomes very small.

The soft magnetic thin film according to this embodiment has a small columnar grain size and good soft magnetic characteristics. This film can be readily obtained by forming, at a high substrate temperature, an underlayer of a given metal or alloy having a thickness of several nanometers so that a great number of nuclei are formed at the initial stage of formation of the soft magnetic thin film, and then superposing the soft magnetic thin film on the underlayer.

The underlayer used in this embodiment is made of at least one metal selected from the group consisting Co, Ni, Fe, Al, Ti, Mo, Cr, V, W and Cu, or an alloy comprising at least one metal. The thickness of the underlayer is preferably in the range of from 2 to 20 nm and most preferably from 3 to 10 nm. This is because with a thickness less than 2 nm, the density of the atom clusters becomes small with a reduced number of nuclei, so that the columnar grains of the soft magnetic thin film have unfavorably a large size. On the other hand, when the thickness exceeds 20 nm, the underlayer makes an ordinary metal or alloy surface, so that the atom clusters serving as the nuclei are undesirably reduced in number.

The soft magnetic layer which may be a single layer or a multilayer is made of at least one alloy which is selected from Fe-Si-Ru alloys, Ni-Fe alloys, Fe-Ge alloys, Fe-Ti alloys and Co-Fe alloys.

The thin-film magnetic head for magnetic recording according to this embodiment makes use of the soft magnetic thin film of the type described above as a pole. When the soft magnetic film is used as the main pole of the magnetic head, high output and high linear bit density can be attained.

This is particularly described by way of examples.

EXAMPLE 1

Various magnetic metals, nonmagentic metals and non-metallic materials were each used to form a 3 nm thick underlayer on a 7059 glass substrate by means of a high frequency sputtering apparatus under conditions of an Ar pressure of 2.7 Pa., a substrate temperature of 400° C. and a making power supply of 175 W. Subsequently, the above procedure was repeated except that the power supply was increased up to 500 W and Fe-6.3 wt%Si-1 wt%Ru alloy was used, thereby forming a 0.2 μm thick soft magnetic thin film on each underlayer. The coercive force Hc (Oe) and permeability μ at 10 MHz of the resultant soft magnetic thin films using various types of underlayers are shown in Table 3 below.

TABLE 3

Underlayer	Coercive Force Hc (Oe)	Permeability (μ)
nil	3	800
	Magnetic Metal:	
NiFe	1.2	1600
Co	1.3	1500
Ni	1.2	1600
Fe	1.4	1200
	Nonmagnetic Metal:	
Al	1.3	1500
Ti	1.3	1400
Mo	1.3	1400
Cr	1.7	1100
V	2	1000
W	1.4	1300
Cu	1.4	1300
	Nonmetal:	
SiO_2	6	400
Al_2O_3	5	500

As will be seen from the above table, irrespective of the types of underlayer material including magnetic metals such as Ni-Fe alloy, Co, Ni and Fe and nonmagnetic metals such as Al, Ti, Mo, Cr, V, W and Cu, the effect of the underlayers on the soft magnetic characteristics is remarkable. As compared with the cases where no underlayer is used or nonmetals such as SiO_2 and Al_2O_3 are used, the coercive force Hc (Oe) is reduced to about one half and the permeability μ increases by

about two times or greater. Thus, the soft magnetic thin films using the metallic underlayers have good magnetic characteristics. Especially, when Ni-Fe alloy, Co, Ni, Al, Ti and Mo are used as the underlayer, the magnetic characteristics are much more improved. The soft magnetic characteristic of the magnetic thin films using the nonmetal unerlayers are poorer than those characteristics of the magnetic thin film free of any underlayer.

EXAMPLE 2

The procedure of Example 1 was repeated using an Al underlayer and a 0.2 μm thick soft magnetic thin film of Fe-6.3 wt%Si-1 wt%Ru while changing the thickness of the underlayer. The resultant films were subjected to measurement of the relation between the thickness of the underlayer and the permeability μ. The results are shown in FIG. 14. As will be seen from the figure, the thickness of the underlayer is preferably from 2 to 20 nm and most preferably from 3 to 10 nm. This tendency was also confirmed when the metals and alloys other than Al were used. Within the thickness range of from 2 to 20 nm, the atoms forming the underlayer was in the form of clusters. At higher substrate temperatures, the clusters were formed as separated, not continuously, in greater numbers. It is considered that these clusters form nuclei at the initial stage of formation of the soft magnetic film, making a small size of columnar grains in the thin film.

EXAMPLE 3

A multilayered soft magnetic thin film having a sectional structure shown in FIG. 15(*a*), which has an Ni-Fe alloy underlayer 34, Fe-6.3 wt%Si-1 wt%Ru alloy thin layers 36 and Ni-Fe alloy thin film intermediate layers 38 formed on a substrate 40, was made under conditions as used in Example 1. Likewise, a multilayered soft magnetic thin film having a sectional structure shown in FIG. 15(*b*), which has an Al underlayer 42, Fe-6.3 wt%Si-1 wt%Ru alloy thin layers 44 and Ni-Fe alloy thin film intermediate layers 46 formed on a substrate 48, was made. The thickness of the Fe-6.3 wt%Si-1 wt% alloy thin films 36 and 44 was 0.05 μm, the thickness of the intermediate layers 38 and 46 was 3 nm, and the thickness of the underlayers 34, 42 was 3 nm. The total thickness of the multilayered soft magnetic thin film was 0.2 μm.

In this example, the underlayers were effective and had a coercive force Hc (Oe) smaller by one half and a permeability u higher by about two times that the case where no underlayer was used. Similar results were obtained when using Ti, Mo, Co, Ni and Fe as the underlayer.

The effect of the underlayer was shown not only with the case where an Fe-Si-Ru alloy single film having the columnar structure or a multilayered soft magnetic thin film having a superposed structure of Fe-Si-Ru and Ni-Fe alloys, but also with Fe-Ge, Fe-Ti and Co-Fe alloys having the columnar structure. The effect became more pronounced in Fe-Si-Ru alloys. In addition, the effect of the underlayer was remarkable when the thickness of the soft magnetic thin film was below 1 μm.

EXAMPLE 4

A thin-film head for vertical magnetic recording having a sectional construction shown in FIG. 16 was made according to a known thin-film formation technique, in which there was used, as a main pole 50, a 0.2 μm thick multilayered soft magnetic thin film having a 3 nm Ni-Fe alloy underlayer, Fe-6.3 wt%Si-1 wt%Ru alloy thin layers and Ni-Fe alloy intermediate layers. This thin-film magnetic head was comprised of a nonmagnetic substrate 52 made of Al_2O_5, TiC, Al_2O_3 or ZrO_3, the main pole 50 of the multilayered thin film construction, a gap layer 54 made of Al_2O_3, SiO_2 or the like, a conductive coil 56 made of Cu, Al or the like, an insulative laer made of polyamide resin or SiO_2, and an auxiliary pole 60 made of Co-Zr-W, Co-Zr, Ni-Fe or the like. The thin-film magnetic head as shown in FIG. 16 and a thin-film magnetic head whose main pole was free of any underlayer were made and compared with each other with respect to linear bit density characteristic. The results are shown in FIG. 17. As will be apparent from the figure, when a 3 nm thick Ni-Fe thin film was formed as the underlayer (curve C), the relative output and linear bit density were higher by about 1.5 times and about 1.2 times than those characteristics of the case using no underlayer (curve D), respectively.

The results of Examples 1 through 4 reveal that soft magnetic thin films which do not involve an increase of coercive force Hc (Oe) and only a slight degree of reduction of permeability when the thickness decreases, can be obtained and that thin-film magnetic heads for vertical magnetic recording using the thin films can provide high output and high linear bit density. Thus, these films and heads can have very high industrial merits.

What is claimed is:

1. In a thin-film magnetic head comprising a nonmagnetic substrate having a major surface over which a main pole, a coil and a magnetic layer are formed, at least a portion of said main pole and said magnetic layer being separated by at least a gap layer, and said coil being located between and insulated from said main pole and said magnetic layer, the improvement characterized in that said main pole consists of a multilayered magnetic film which comprises at least two unit magnetic films provided substantially parallel to said major surface of said substrate, each of said at least two unit magnetic films having a thickness of from 0.05 to 0.9 μm and comprising a plurality of ferromagnetic layers each having a thickness of from 0.01 to 0.2 μm and at least one first intermediate layer made of a ferromagnetic, nonmagentic or antiferromagnetic material having a thickness of from 1 to 10 nm provided between selected ones of said plurality of ferromagnetic layers, and at least one second intermediate layer made of a 10 to 40 nm thick nonmagnetic or antiferromagnetic material provided between the at least two unit magnetic films, wherein said plurality of ferromagnetic layers, said at least one first intermediate layer and said at least one second intermediate layer are provided substantially parallel to said major surface of said substrate.

2. A thin-film magnetic head according to claim 1, wherein each of said at least two unit magnetic films has a thickness of from 0.09 to 0.2 μm.

3. A thin-film magnetic head according to claim 1, wherein each of said plurality of ferromagnetic layers has a thickness of 0.04 to 0.12 μm.

4. A thin-film magnetic head according to claim 1, wherein said at least one first intermediate layer has a thickness of from 2 to 8 nm.

5. A thin-film magnetic head according to claim 1, wherein said at least one second intermediate layer has a thickness of from 15 to 30 nm.

6. A thin-film magnetic head according to claim 1, wherein said ferromagnetic layers are made of a mate-

rial selected from the group consisting of an Fe-Si alloy and an Fe-Si-Ru alloy.

7. A thin-film magnetic head according to claim 1, wherein said at least one first intermediate layer is made of a Ni-Fe alloy.

8. A thin-film magnetic head according to claim 1, wherein said at least one second intermediate layer is made of a material selected from the group consisting of SiO_2 and Al_2O_3.

9. A thin-film magnetic head according to claim 1, wherein an underlayer made of a metal or alloy is provided on and parallel to said major surface of said substrate and said main pole, said coil and said magnetic layer are formed on said underlayer.

10. A thin-film magnetic head according to claim 9, wherein said underlayer has a thickness of from 2 to 20 nm.

11. A thin-film magnetic head according to claim 9, wherein said underlayer has a thickness of from 3 to 10 nm.

12. A thin-film magnetic head according to claim 9, wherein said underlayer is made of at least one metal selected from the group consisting of Co, Ni, Fe, Al, Ti, Mo, Cr, V, W and Cu.

13. A thin-film magnetic head for magnetic recording comprising a substrate having a major surface, an underlayer formed on and parallel to said major surface of said substrate, a first pole made of a soft magnetic thin film formed on and parallel to said underlayer, a coil and a second pole, at least a portion of said first and second poles being separated by a gap layer, said coil being located between and insulated from said first and second poles, and said underlayer being made of a metal or alloy and having a thickness of from 2 to 20 nm.

14. A thin-film magnetic head according to claim 13, wherein said soft magnetic thin film has a multilayer structure.

15. A thin-film magnetic head according to claim 13, wherein said first pole is a main pole of a thin-film magnetic head for vertical magnetic recording.

16. A thin-film magnetic head according to claim 13 or 15, wherein the underlayer is made of a metal selected from the group consisting of Co, Ni, Fe, Al, Ti, Mo, Cr, V, W, Cu and mixtures thereof and alloys comprising at least one metal defined above.

17. A thin-film magnetic head according to claim 13 or 15, wherein said soft magnetic thin film is made of at least one alloy having a columnar structure and selected from the group consisting of Fe-Si-Ru alloys, Ni-Fe alloys, Fe-Ge alloys, Fe-Ti alloys and Co-Fe alloys.

18. A thin-film magnetic head according to claim 13 or 15, wherein said underlayer has a thickness of from 3 to 10 nm.

* * * * *

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DOCUMENT-IDENTIFIER: JP 54068619 A

TITLE: PRODUCTION OF MAGNETIC HEAD

PUBN-DATE: June 1, 1979

INVENTOR-INFORMATION:
NAME
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INT-CL (IPC): G11B005/251, G11B005/42 , G11B005/52

US-CL-CURRENT: 29/846

ABSTRACT:

PURPOSE: To narrow the track and gap in magnetic head for home-use VTR, by forming a resist pattern with glass sputtering film for defining gap length of ferrite head.

CONSTITUTION: A gap end face 2 of one ferrite block 1 is planished to mirror- finish, and the degenerated layer is removed by electroetching. A glass sputtering film 3 having a thickness corresponding to the specified gap length is deposited on the face 2, and a pattern 4 is formed. At this time, width T of the film 3 is controlled at t+2a (t: required track width; a: required etching amount). The block 1 is electroetched, using the film 3 as the resist, and the front butt end is constructed into a comb form having width of (t). This comb-like ferrite block 5 and another ferrite block 7 having a winding window 6 are joined end to end, and molded and bonded together with glass 8. Then, the head core 9 is cut and separated along the dot-dash line.

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Abstract Text - FPAR (2):

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G 11 B　5/251		102 E 504	6161—5D	
G 11 B　5/42		102 E 501	6161—5D	発明の数　1
G 11 B　5/52			7630—5D	審査請求　未請求

(全 3 頁)

⑤磁気ヘッドの製造法

㉑特　　願　昭52—135916

㉒出　　願　昭52(1977)11月11日

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明　　細　　書

1、発明の名称

磁気ヘッドの製造法

2、特許請求の範囲

(1)　少なくとも一方がくし形に形成された2個1対のフェライドブロックを有し、上記2個1対のフェライトブロックの少なくとも一方のギャップ対向面に形成したガラス膜の制御のもとに所定ギャップ長を有するように突合わせ接合する磁気ヘッドの製造法において、くし形フェライトブロックは電解エッチングされたギャップ対向面に付着されたガラス膜をレジストパターンとして使用して電解加工することにより製作し、その後他方のフェライトブロックに突合せることを特徴とする磁気ヘッドの製造法。

(2)　ガラス膜はスパッタリングにて形成することを特徴とする特許請求の範囲第1項の磁気ヘッドの製造法。

(3)　ガラス膜は高熱処理して付着させることを特徴とする特許請求の範囲第1項記載の磁気ヘッドの製造法。

(4)　ガラス膜レジストパターンはスパッタエッチングにて形成することを特徴とする特許請求の範囲第1項記載の磁気ヘッドの製造法。

(5)　ガラス膜は所定ギャップ長に等しい厚みに付着することを特徴とする特許請求の範囲第1項記載の磁気ヘッドの製造法。

3、発明の詳細な説明

本発明はフェライトを用いた磁気ヘッドの製造法にかかりとくに高性能の狭トラック狭ギャップ化に適した磁気ヘッドの製造法に関するものである。

家庭用ビデオテープレコーダ(以下VTRという)に用いられるビデオヘッドにはフェライトが多く用いられている。このフェライトビデオヘッドはVTR本体およびカセットの小型化をはかるための高密度化の方向に沿い狭トラック化および狭ギャップ化がなされ、一方、画質の維持向上の点からより高性能化がはかられている。

一般にフェライトヘッドの製造にあたっては機

械加工を主とした形状加工や研摩加工が施こされている。しかしながら、機械加工では本質的にフェライトが加工劣下を生じてフェライト本来の磁気特性が劣下し、ヘッド性能を低下させていた。この問題は狭トラック化に伴ないコア厚が薄くなるほど、また狭ギャップ化に伴ないギャップ長が狭くなるほど著しく、とくに機械加工によるギャップ突合せ面の加工変質層の存在は記録磁界の拡がりによる記録減磁や実効ギャップの拡がりによるギャップロスなど各種の損失要因となっていた。一方、形状加工の点からも実効トラック幅が小さくなるにつれてフェライトの欠けが頻発し、歩留りが悪くなるものであった。また、寸法精度も加工条件に大きく左右され安定した条件の設定、維持が困難なものであった。

以上のように機械加工を主体としたヘッド製造方法では高密度高性能ヘッドを高歩留りで製造するには限界があり、これらの問題を解決する新規な加工法が望まれている。

発明者らは先にフェライトの電解研磨加工において、一般の金属の電解研磨に用いられている電解液と同様にその電圧－電流特性に平担部を有する電解液を見出し、その電解液を用いたフェライトヘッドの製造の有用性を提案した。

上述の電解液を用いて実効トラック巾を形成するに際してフォトレジスト被覆との作用が考えられる。しかしながら、フォトレジスト被覆を用いたパターン形成ではフォトレジスト工程の煩雑さ、およびレジスト寸法精度の点で安定性に欠け、またレジストの寄りのためステ部が必要になるなどの問題があった。また、フォトレジスト材の耐エッチング性，密着性，膜厚などの諸条件の設定も面倒なものであった。

本発明はこのような従来の欠点を解消するものであり、以下、本発明の磁気ヘッドの製造法について実施例の図面と共に説明する。

まず、第1図Aに示すように2個1対の片方のフェライトブロック1を用意する。このフェライトブロック1のギャップ突合せ面2は通常の機械鏡面仕上げしたのち加工変質層を電解エッチングで例えば0.6μm程度除去する。電解液は硫酸とリン酸の等容量混合液を用いる。次に第1図Bに示すように上記フェライトブロック1のギャップ突合せ面2に所定ギャップ長に相当する厚みのガラススパッタリング膜3を付着させる。このガラススパッタリング膜3は付着後高熱処理で焼つけてもよいし、またそのままにしておいてもよい。次に第1図Cのように上記フェライトブロック1の前部突合せ部分において、実効トラック幅部分を形成するためのパターン4を形成する。この時、ガラス膜3の幅Tは所要トラック幅tと、所要エッチング量dの2倍の和に相当するよう設定する。パターン形成はスパッタエッチングイオンエッチング等で行なう。

上述のようにガラス膜3によるパターン4を形成したフェライトブロック1は次に上記ガラス膜3をレジストとして上述のような電解液にて電解エッチングする。この電解エッチングにより上記フェライトブロック1の前部突合せ部分は第2図に示すように所要トラック幅tを有するくし形の形状に形成される。次に第3図に示すように上述のくし形フェライトブロック5ともう一方の巻線窓6を有するフェライトブロック7を突合せ、ガラス8にてモールド及び接着を行なう。この時ギャップ長10は先のガラススパッタ膜3で決まり、このスパッタガラスはモールド，接着ガラスよりも融点が高いものが用いられる。しかるのち、1点鎖線で示すごとく切断分離して第4図Aに示すようなヘッドコア9を得る。

第4図Bは本発明の磁気ヘッドの他の構成例を示す。この第4図Bのヘッドコア11を得るには、2ケ1対の両方のフェライトブロックに上述と同様の実効トラック幅加工を施こせば良く、この時ガラススパッタリング膜はそれぞれ所定ギャップ長の半分の厚みにすればよい。

尚、上記の実施例では電解液を硫酸，リン酸の等容量混合液のものを使用したが、これ以外にも上記混合液を主体として他に酸、添加剤を加えたものでもよい。

以上のように本発明は、ギャップ長規制用ガラ

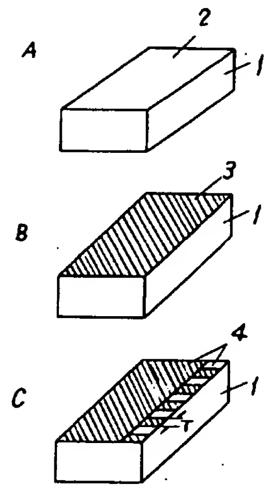
ススパッタリング膜にてレジストパターンを形成するので、製造プロセスの合理化および、高精度化が実現できるものである。しかもレジストパターンがガラス膜であるため数μm の実効トラック幅でも加工でき、従来の機械加工では実現不可能な超狭トラック幅のヘッドも実現できるものである。

4、図面の簡単な説明

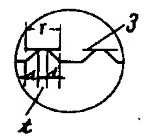
図面は本発明の磁気ヘッドの製造法の一実施例を示し、第1図A，B，Cはガラス膜レジストパターンの形成過程を説明するための図、第2図は実効トラック幅の形成過程を説明するための図、第3図は突合せフェライトブロックの斜視図、第4図A，Bはヘッドコアの斜視図である。

1……フェライトブロック、2……ギャップ対向面、3……ガラス膜、4……レジストパターン、5……くし形フェライトブロック、6……巻線窓、7……フェライトブロック、8……モールド接着ガラス、10……ギャップ長、9，11……ヘッドコア。

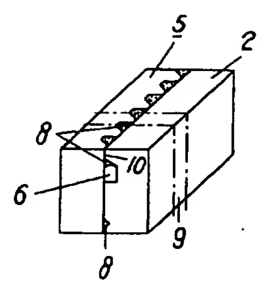
第1図



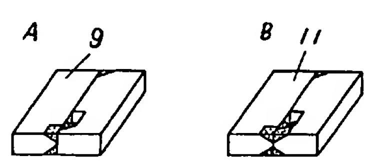
第2図



第3図



第4図



glass 8. Then, the head core 9 is cut and separated along the dot-dash line.